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SOCIAL FACTORS ASSOCIATED WITH TRAFFIC GENERATION IN A METROPOLITAN AREA OF 75,000 POPULATION

by

Robert W. Janes

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Professor of Sociology,
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University of Illinois
in cooperation with

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ABSTRACT

DATA FROM AN ORIGIN-DESTINATION SURVEY IN A MEDIUM SIZED CITY WERE ANALIZED FOR RELATIONSHIPS BETWEEN HOUSEHOLD CHARACTERISTICS AND LOCAL TRAFFIC GENERATION. FINDINGS SUGGESTED THAT SOCIO-ECONOMIC TRAITS OF HOUSEHOLDS WERE MOST HIGHLY CORRELATED WITH TRAFFIC GENERATION OF COMMUNITY ZONES, BUT THE TOTAL VOLUME OF TRAFFIC GENERATED IS APPARENTLY INFLUENCED BY A COMPLEX OF VARIABLES ACTING IN COMBINATION.

HOUSEHOLDS SHOW A GREAT VARIATION IN TRIP GENERATION, AND A SMALL PROPORTION OF HOUSEHOLDS ACCOUNT FOR A LARGE RATIO OF TRIPS. THUS, ARITHMETIC MEANS ARE POOR INDICATORS OF THE CENTRAL TENDENCY OF A DISTRIBUTION OF THE NUMBER OF TRIPS MADE BY A SET OF HOUSEHOLDS. TWO-VEHICLE HOUSEHOLDS PRODUCE ONLY ONE-THIRD MORE VEHICULAR TRIPS, ON THE AVERAGE, THAN ONE-VEHICLE HOUSEHOLDS. INCREASE IN THE NUMBER OF TWO-VEHICLE HOUSEHOLDS WILL NOT, THEREFORE, INCREASE PROPORTIONATELY THE VOLUME OF LOCAL TRAFFIC GENERATION. THE ONE-VEHICLE HOUSEHOLDS OF A COMMUNITY SHOW A CONSIDERABLY GREATER VARIATION IN AMOUNT OF TRIP-GENERATION THAN DO TWO-VEHICLE HOUSEHOLDS. AN INCREASE IN THE PROPORTION OF TWO-VEHICLE HOUSEHOLDS SHOULD, THEREFORE, MAKE LOCAL TRAFFIC VOLUMES MORE PREDICTABLE.

THE PATTERN OF TRAFFIC INTERCHANGE BETWEEN ZONES OF A COMMUNITY APPEARS TO REPRESENT A "PUSH-PULL" MODEL IN WHICH THE PUSH IS HOUSEHOLD TRAFFIC GENERATION AND THE PULL IS THE SATISFACTION OF TRIP PURPOSES BY FACILITIES DISTRIBUTED AT VARYING DISTANCES FROM HOUSEHOLDS. REDUCTION OF THE "PUSH-PULL" MODEL TO A FORMULA BASED ON HOUSEHOLD DENSITIES PER SOME GEOGRAPHIC MEASURE SUCH AS ACRES WOULD BE DESIRABLE. POSSIBILITY OF SUCH A REDUCTION IS COMPLICATED BY THE FACT HOUSEHOLDS WITH HIGHEST RATE OF TRIP GENERATION ARE NOT LOCATED IN AREAS CONTAINING THE HIGHEST DENSITY OF VEHICLES. DISTANCE TRAVELED IN TRAFFIC INTERCHANGE BETWEEN ZONES APPEARS TO BE DIRECTLY PROPORTIONAL TO THE ACTUAL NUMBER OF DISTANCES BETWEEN ALL SURVEY ZONES. DISTANCE TRAVELED IN ALL TRIPS, THEREFORE, APPEARS TO BE CONDITIONED BY A PHYSICAL PRINCIPLE, WHILE THE ACTUAL GENERATION OF TRIPS THEMSELVES APPEARS TO BE A PRODUCT OF SOCIO-ECONOMIC DIMENTIONS OF HOUSEHOLDS.

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GLOSSARY

Survey area	The land area within the city limits of Champaign-Urbana and the adjacent land area within a distance of approximately two miles from these city limits.
Internal survey	The phase of the Champaign-Urbana origin-destination survey by which traffic data were secured through interviews of a sample of residents living in selected dwellings and through interviews of a representative sample of the operators of trucks, taxis, and buses.
Dwelling unit or household	A group of rooms or a single room occupied or intended for occupancy by a family, a group of persons living together, or a single person living alone.
Student household	One of the sample of households based on the student directory of the University of Illinois.
Non-student household	One of the sample of households based on the city directory of Champaign-Urbana.
Survey zone	One of the many segments, approximately sixty, into which the survey area was divided for the purpose of describing location of households and for aspects of analysis.
Vehicle trip	One-way travel by one vehicle between point of origin and point of destination, normally a trip between two zones.
Internal traffic	Traffic having both point of origin and point of destination within the survey area.
Desire line	A straight line drawn between the point of origin and the point of destination of traffic without reference to existing streets and highways.
Central Business District (CBD)	The central downtown area which is devoted almost exclusively to commercial, administrative, and professional activities. In the case of the Champaign-Urbana survey area, there were two such areas, downtown Champaign, Zones 101 and 102, and downtown Urbana, Zone 301

Traffic interchange	Interchange of vehicular trips between two sections of the survey area, normally zones.
Developed acres	Sections of the survey area for which a plat showing utilities and facilities has been filed with and approved by city officials and which is shown on the official city map as zones for purposes such as residential or commercial activity.
Socio-economic level of zone	Estimated level of average occupational and income ranking of households in a zone -- partially reflected in residential desirability of areas in a zone.
Cumulative scales	Measures of the attributes of a subject. These measures are developed through rules for scale construction. Example, scale of occupational level of members of households.
Guttman scale	A type of cumulative scale used to measure a number of socio-economic attributes of households described in the present study.
No. 1 card	The IBM punch card which contained data on household characteristics as gathered from the household survey.
No. 2 card	The IBM punch card which contained data on each vehicular trip reported in the household survey.
Zone homogeneity	The degree to which the households of a zone were similar in respect to measures of socio-economic attributes such as value of residence, value of vehicle, occupational level, etc.
Regression analysis	Mathematical description of the relation between two or more variables in terms of concommitant variations about a linear definition of the relationship.
Coefficient of correlation, R	Statistical measure of relationship between two variables assumed to be continuous and rectilinear. Ranges from 1 to -1, and the closer the value of R is to either of these extremes, the greater the association between the variables. Should be employed only for a relatively large number of cases, 30 or more.

Pearson product-moment r or zero-order r	Can be interpreted as R.
Coefficient of multiple correlation	A coefficient of correlation which statistically measures the variation of several variables in combination as it is associated with the variation in one dependent variable.
Homoscedasticity	The degree to which the range of values about the linear definition of the regression between two variables is uniform. Coefficients of correlation are most accurate as measures of association between variables whose relation shows this quality.
Variance	The sum of squares of the deviations about the line of regression between variables. Analysis of variance constitutes a useful test of significance of difference between various statistical distributions.
Factor analysis	A statistical technique for identifying underlying components or factors which may exist within a set of intercorrelated variables. The technique normally is applied to a group of variables whose interrelations are shown through coefficients of correlation. Identified factors represent patterns or combinations of variables which are most likely related among themselves.
Factor loading	The degree to which a particular variable in a set of interrelated variables is associated with a particular factor identified in this set. The values of factor loadings are the same as the range of values of coefficients of correlation. The closer the value of the loading approaches to 1, the more important is this variable as a component of the factor.
Orthogonal factor	The mathematical and logical independence of a factor from all other factors identified in an analysis makes it orthogonal to other factors. Such a factor would not be expected to share a high loading on the same variable with other factors. Orthogonal factors are distinguished from "oblique" factors which are not statistically independent of each other.

Varimax program	A computer program devised at the Digital Computer Laboratory of the University of Illinois to provide the operations necessary for a factor analysis on the ILLIAC Computer, Mark I.
Tests of significance	Statistical techniques which are used to make inferences about properties of statistical distributions, especially likeness or difference between them. Chi-square, the "t" test, the F test, the Mann-Whitney test, etc., are examples of such tests.
Ecological correlation	Coefficients of correlation computed on the basis of measures applying to territorial groupings as a whole rather than on correlations between the cases contained within the grouping. For example, the correlation coefficient between the average number of vehicles per zone household and the average number of vehicular trips per zone household is an ecological correlation. If this correlation were computed for each individual household in the survey area, it would be an individual correlation.
Ecological fallacy	An ecological correlation between variables which may be spuriously high because allowance was not made for the conditions represented by the group measures used in the correlation.

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I. INTRODUCTION

A. GENERAL

This study is an exploration of the relation between household characteristics and local traffic generation. The source of the data was the Origin-Destination Survey of Champaign-Urbana, Illinois, made in the spring of 1958. The central hypothesis of the study was that variations in the socio-economic characteristics of households account in a large measure for differences in the production of traffic by the various zones of a community. The testing of this hypothesis involved a number of research problems of both practical and theoretical interest relative to understanding traffic generation.

B. PROBLEMS OF THE RESEARCH

The practical concerns and interests of the study included first, the question, was it possible to more precisely define the categories of information secured from a household survey so that these data may be statistically correlated among themselves? The types of categories involved in this question are socio-economic traits of households which might be significant for traffic generation. A second problem involved the possibility of discovering presently unutilized social data which might serve as a substitute for the traditional origin-destination survey or which might, if utilized, reduce the cost of making origin-destination surveys. A third interest was that of establishing a rationale for predicting future traffic volumes, both in the subject community and in similar communities, on the basis of anticipated changes in the socio-economic characteristics of households.

The practical orientation of the research also included interests in two technical aspects of the phenomenon of traffic generation in American communities. One issue here was the question of the degree to which the household, as defined in the origin-destination survey, is the basic unit of traffic generation. Secondly, there was an interest in determining the degree to which local neighborhoods and/or survey zones as defined in an origin-destination survey represent homogeneity by household in rate of traffic generation.

The theoretical interests of this study focused on several issues: first, to what extent can a community be analyzed as an interacting system in which local areas produce and/or attract traffic according to some predictable pattern or formula? This was done to determine if it would be possible to arrive at a general statement or a general proposition which might predict the total amount of traffic generated in certain types of communities. A second problem pertained to the study of indices of traffic such as the number of trips of various lengths which are made in an American community, with an eye to discerning whether these distributions appear to be consequences of specific social or physical aspects of particular local communities. The aim here is to explore the question does traffic generation in an American community seem to represent particular local conditions or is it a consequence of some economic or efficiency criteria applicable to many communities. If a general proposition about traffic generation can be demonstrated, it would serve both to predict traffic volumes and to suggest rational explanations about kinds of mass behavior in our society such as those exemplified by the use of private vehicles for transportation.

A final investigative interest was in traffic generation patterns of a smaller metropolitan community with a highly specialized economic base. Information on such a community might serve to complement the well-known studies of major metropolitan areas such as Detroit and Chicago. The central concern here might be described as being a comparative interest in size and economic specialization as major factors effecting patterns of community traffic generation. A secondary purpose of such a description of traffic patterns was to provide a basis for a future follow-up study of the Champaign-Urbana area after the present links in the interstate system which are being built through the Champaign-Urbana area are completed. If a base could be established from the present study, a future study could be made to examine the possible influences of the completion of the links of the interstate system upon the local traffic generation patterns once the interstate connections have been completed.

Major stimulus to the research of the present study were analyses and reports sponsored either directly or indirectly by the Federal Bureau of Public Roads. The principle guide to the design of this study was the Detroit Traffic Study reported in 1955.[(1)*] Many of the tables and findings

*The superscript numbers in parentheses refer to entries in Chapter VIII, References.

of the present study are intended to be comparable to the categories used in Chapter Five of the Detroit study. The comprehensive study of the conditions of traffic generation in Chicago also served to support and to give clues to the course of the development of the present study.(2) Other previous research which has been important in formulating the design and interest of this study included that by Curran and Stegmaier,(3) Wynn,(4) Sharpe, Hansen, and Hammer.(5) These reports and others like them have set the framework of the interest in the Champaign-Urbana research project. This project, however, emphasizes the role of the household in the traffic generation process and much of the analysis is limited to the findings from the household survey.

The aim of the present analysis, therefore, is to come to some understanding of basic dynamics of traffic generation in a smaller American city. This understanding is based on the study of certain social traits of the trip generating population. Since the study was sponsored jointly by the Department of Sociology and the Illinois Cooperative Highway Research Program at the University of Illinois, much of the research emphasis and many of the techniques of investigation used herein were those which are characteristically employed by sociologists in their studies. Also, the findings provide grist for the sociological mill because they contribute understanding to one of the major areas of mass behavior in our contemporary society; that is, the use of the passenger vehicle. The conclusions of the study will show that many facets of the use of passenger vehicles can be explained in terms of the household and neighborhood traits of the community. Such a relation, obviously, is both of interest to a sociologist and is, to some extent, an extension of the sociological approach to human behavior. The fact that certain patterns of traffic generation, notably the distributions of the number of trips by distance traveled, suggests a rational economy of familial resources is also an aspect of human behavior with sociological significance.

However, the major contribution of the study in a practical or technical sense would be in what it adds to understanding the generation of traffic in a community. The predictions about future traffic volumes in our communities may be regarded as an application of a social science explanation of human behavior, but the basic interest for the average traffic engineer or planner of these findings is in how they aid the engineering and planning functions of community road systems. It is hoped that the report of the Champaign-Urbana study as it deals with the types of research problems outlined above will make such a practical contribution to the activities necessary to cope with the problems created by present and future traffic generation in American communities.

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II. THE COMMUNITY AND THE 1958 ORIGIN-DESTINATION SURVEY

The site of the Origin-Destination survey which supplied the data for the present study was Champaign-Urbana, Illinois. This bi-partite community consists of two contiguous, but politically independent cities, located in Champaign County in East-central Illinois. It is the site of the main campus of the University of Illinois and this enterprise is the basic employing agency of the community. The population of the two cities at the time of the survey was estimated at 72,000, of whom some 17,000 were students at the University. The other community of significant size in the county is Rantoul, site of Chanute Air Force Base. Rantoul is located 14 miles north-east of Champaign-Urbana. This community with its air base personnel contained a population, at the time of the survey, of approximately 22,000 persons.

A. COMMUNITY BACKGROUND

Champaign-Urbana is the center for agricultural, industrial, commercial, and transportation activities. Total industrial employment in 1958 was estimated at 2,500. Because of the presence of the University, whose students are included in the present census definition of the local population, the community has shown one of the most rapid rates of growth among the smaller metropolitan areas in the state of Illinois.

The communities are located roughly 140 miles south of Chicago. They are the point of intersection of several rail lines and will shortly be a point of intersection of major segments of the interstate highway system. Interstate 74 passes through the northern fringe of the two communities and Interstate 57 is routed along the western fringe. A state freeway terminating with Interstate 57 within the city limits of Champaign is under construction to Decatur and will probably be extended to Springfield. As a medium-sized community, Champaign-Urbana is a rather unusual focus of the facilities of the interstate system.

Internally, the local street system of the two cities has taken form according to the traditional gridiron pattern. There are a number of discontinuities in the street system and other barriers to easy traffic flow, mainly railroad tracks and crossings and the location of the University, which is part of the boundary between the two communities. New housing developments have extended the city limits of both communities. The main axes of these developments have been southwesterly and southeasterly, although the development of the interstate system promises to lead to new developments to the north and west. At present, the community is served by a series of marked state routes such as U.S. 45 and 150 and Illinois 10. Moreover, there is a network of unmarked routes reaching out into adjacent areas and nearby towns and villages.

The vehicle registration in Champaign County at the time of the survey was slightly less than 50,000. In general, the ratio of county vehicular registration to state registration has been relatively constant since 1950. The data for registration for Champaign-Urbana were not available and this number of vehicles could not be accurately measured over the period of a year because of the fluctuations in the number of students in residence who own vehicles. Student vehicles in the spring semester, the time of the origin-destination survey, accounted for almost one-quarter of all vehicles reported in the household survey, although student-owned vehicles did not contribute proportionately in terms of their numbers to the total volume of local traffic.

B. CONDUCT OF THE ORIGIN-DESTINATION SURVEY

The general design of the survey and the tabulation of its results were reported by the Division of Highways of the Department of Public Works and Buildings of the State of Illinois.[6] The design of the survey was that normally utilized for communities of this size. There were several minor modifications as noted below. Originally 60 zones were mapped out as the basis of the study as shown in Figure 1. In the actual analysis, however, only 41 of these zones were studied because the other 19 contained either too few households or too few households occupied by non-student families.

The survey was made in the late spring of 1958 under the supervision of the district office in Paris, Illinois. It was based on a 12.5 per cent sample of households drawn from the city commercial directory and from the University directory of students. 4,400 interviews with household units were completed. Of these slightly less than 2,000 were students living in some kind of dwelling unit devoted primarily to student residency. The subsequent analysis of both the internal survey data and the household survey data showed the average number of weekday trips to be approximately 225,000. Internal vehicular trips accounted for approximately 87 per cent of this total, of which 21 per cent terminated or originated in the Champaign Central Business District (CBD) and 9 per cent in the Urbana CBD. 27 per cent of all internal vehicular trips either originated or terminated in the campus area. However, since the campus is both a place of residence for vehicle-owning households, as well as a trip destination, this high proportion of traffic generated about the campus area does not mean that the attraction of the campus is equal to or necessarily larger than that of the CBD's.

In terms of internal trip purposes, 29 per cent were made for work or business, 9.5 per cent for shopping, 12 per cent for social-recreational, 8.5 per cent for school, 5 per cent miscellaneous, and 36 per cent to homes. When these figures are compared to the national averages for selected urban areas as computed by Curran and Stegmaier, Champaign-Urbana is close to the average for work, personal business, social-recreational, and shopping; it is above average for school and below average for home and miscellaneous. In general, then, it would not appear that the presence of the University has created an atypical situation in respect to the purposes for which trips are made. In fact, it is interesting to note the rather low ratio for social-recreational trips given the large proportion of students in the population. This may be due to the concentration of student recreation on the week-ends, or to the fact that many of the student interviews came at the end of the semester.

The interview was the basic source of information used in this study. The standard Manual of Instructions of the Bureau of Public Roads was used to guide the interviewers with certain modifications, including items on the socio-economic type of the zone, make and year of car, the length of residence of the household, age of persons over five years of age, and the occupation and industry of drivers and passengers. The conduct of the household survey followed the standard pattern, and insofar as non-student households were concerned, only the normal difficulties in such interviews appeared. The rate of refusal was very low, although some difficulty was encountered because of an apparent high rate of residential mobility in multi-family dwellings.

The student sample constituted a much more difficult problem in securing interviews. One reason for this problem was the decision to treat each separate student listed in the University directory as an independent household. This meant a much larger number of interviews than had originally been anticipated on the assumption that the average household would contain three or more persons. The problem was further complicated by the fact that many students had left school since the preparation of the directory. With the cooperation of the University authorities, however, arrangements were made to interview the students at campus locations rather than in their residences, as student schedules made it difficult to locate them in their residences during the day or at other regular times. The student interviews were completed with an acceptable proportion of incompleted interviews due to the fact that students could not be located.

The completed interview schedules were processed according to standing procedures. They were coded and then forwarded to the Springfield offices of the Bureau of Research and Planning for punching on IBM cards and tabulation. The original tabulations and preparation of the decks of punched cards for the household interviews were completed in Springfield. Duplicate decks were returned to the research projects in Champaign-Urbana where the analyses were begun based on new tabulations of pertinent data.

The major statistical work at the University of Illinois campus was done at the Statistical Service Unit using standard IBM equipment, such as collators and sorters or the IBM 1401. Other statistical analysis was accomplished through the facilities of the Digital Computer Laboratory of the University of Illinois employing the Illiac Mark I and the various computer programs already prepared by the staff of the Laboratory. The principal manipulations using the Illiac computer were the factor analysis and the computation of regression analysis.

The research operations and activities of the project were carried out by graduate student research assistants under the direction of the project supervisor. The development of the project findings were reviewed annually by the Advisory Board and much of the research followed the suggestions and critiques made by the members of the Board. The principal work of the project took place between the fall of 1959 and the fall of 1963. The project was one of the three which worked with the data of the 1958 survey, and there was considerable interchange of findings and materials developed by the three projects, all of which began and concluded their work at approximately the same dates.

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III. HOUSEHOLD CHARACTERISTICS AND LOCAL GEOGRAPHIC UNITS AS CRITERIA OF TRAFFIC GENERATION

Analysis of data on local traffic generation may call for definition of a unit which is basic in generation of traffic in a community. The present study assumed that the household is such a prime traffic generating entity. Information on such basic units may be summarized by categories of geographic areas. For example, it would have been possible to analyze all 4,400 records of household interviews as independent cases ungrouped by any geographic criterion. A second alternative would be to group all households by three or four rings or sectors of the community and then analyze the difference in traffic generation by these territorial classifications. If the first alternative were adopted as the research design, the findings would have emphasized the influence which household characteristics have on traffic generation independent of the role of the spatial location of the household. The second alternative, or some modification of it, which involves classifying households by geographical contiguity would indicate influences by area. As a device it introduces, however, a statistical bias because it is a well-known fact that households in contiguous areas of most American communities tend toward some homogeneity in socio-economic class characteristics. This fact implies that the households as cases in a statistical universe are not independent of each other in terms of the criteria for study because both neighborhood of household and social class of household are linked variables. Analysis of the findings based on the second alternative, therefore, would compound the influence of socio-economic class of household with the influence of the location of the household on traffic production.

This chapter is concerned with the choice of study design given this range of alternatives. Each approach was tentatively explored as to the promise, difficulties, and possibilities it offered. One consideration which was kept in mind was that traffic generation constitutes a practical problem at the community level because of the variation in the volumes of traffic generated by geographical sectors of a community. Therefore, a prediction of the estimated future traffic volumes to be generated by sectors would be most useful for the community planner and highway engineer. It appeared that although the alternative of grouping cases by some geographic locality might not give as reliable theoretical insights into how household traits were associated with traffic generation, this method would give more practical understanding of community traffic generation. This second alternative, however, was selected only after making a number of analyses using various geographic classifications of the data. The steps leading to the choice of this strategy of analysis are discussed below.

A. SEPARATION OF STUDENT AND NON-STUDENT DATA

The original summaries of data from the household survey combined both the student and non-student households. The first problem undertaken by the project was to determine, in respect to traffic generation, whether these two types of households were so different that the student and non-student data should be separated and analyzed independently. The student households had accounted for almost half of the household interview survey. Student vehicles, however, had accounted for only about one-fourth of the number of household vehicles reported in the survey and had generated only about one-fourth of the passenger trips reported. The difference between a student household, which normally consisted of one student living either in a residence hall, a fraternity or sorority house, or a student rooming house, and the non-student household, usually composed of at least a married couple and/or other related persons, made such a separation appear reasonable.

A justification for such a separation was further supported by comparing the traits of these two types of households in respect to the coefficients of correlation of their household characteristics with trip generation by the household. The household survey deck was divided into student and non-student households and product-moment correlations computed between six household characteristics and the number of passenger trips for both types of households. The results of this procedure are shown in Table 1, which compares the student and non-student samples in terms of these same household characteristics.

In this table the difference is marked between the two sets of households in respect to item number 7, number of trips generated by the household. The differences in respect to this item suggest that these are two kinds of populations in regard to pattern of trip generation. It, therefore, seemed reasonable to treat these two categories separately in analyzing the relation between traffic generation and household characteristics. The principal effort of the study was devoted to the analysis of the non-student population because it was assumed that the findings relative to non-student households would have a greater applicability to other communities. The student sample, however, is of interest because of the information and insight which it gives to the contribution of a special or institutional population to the traffic volume of a particular community. Comment will be made on this point later in the report.

Table 1 is of further interest because it represents a correlation of traits by household with passenger trip generation by household for a whole community. The data of this table are not classified by neighborhood or survey zone. They represent levels of statistical correlation which are secured when household information is correlated without being grouped by geographical location. The significance of these total community correlations will become clearer when they are compared to results secured by grouping data by zone or neighborhood within the community.

B. SELECTING SURVEY ZONES FOR ANALYSIS

The separation of the student from non-student households raised the question of whether all survey zones still contained enough non-student cases to be considered for analysis. Although sixty zones had originally been utilized in the design of the household survey, in at least seventeen of these zones too few non-student households were drawn by the sampling procedures of the household survey for the averages of these zones to be used with any confidence in statistical correlations using averages. Also, several zones were so predominantly student in composition that it did not seem advisable to use them. It was finally decided to use any zone which contained more than ten households and in which the majority of these households were not inhabited by students. With these criteria forty-one zones were selected to be analyzed as geographical areas representative of the traffic generating potential of non-student households. (See Tables A1 - A4, Appendix A.)

The use of measures of social characteristics of households grouped by geographical area and correlated with the traffic generation of the areas was the second alternative for analyzing influence on traffic production noted above. The measures used were in most cases the arithmetic averages for the household in each zone. Examples of such household traits were the average number of persons per household, the average number of cars per household, the average estimated value of household structure, etc. For several measures the percentage value for the whole zone was used; these included the per cent of households with vehicles and the per cent potential trip-makers in all families making trips. Other measures included indices which were applied to all households in a zone based on some trait of the zone. For example, the estimate of the distance of the zone from the CBD was to the nearest of two CBD's from a central point in the zone. One value for the house-type index and for the occupational index was applied to each zone. Approximately thirty such measures which served as a summary or modal description of a zone in terms of characteristics of households and their members were developed in the course of the study, but most analysis was concentrated on less than a dozen of these household attributes.

It had been assumed that zones would be largely homogeneous in respect to household traits, especially those linked to social class such as occupation, value of structure, and age of vehicle. It appeared necessary to check this assumption on the actual data for the forty-one zones, for if the zones were heterogeneous in respect to household traits, the averages or indices for the social characteristics which were correlated with volumes of traffic generation would not be representative of the whole set of households. The assumption was tested by constructing a Guttman-type scale which showed the degree to which a zone varied internally in respect to the combination of measures of occupation, value of structure, and age of vehicle. (See Appendix C for construction of scales.) The scale of heterogeneity reflected the consistency of ranking of a zone on these measures and the results of this scaling procedure are shown in Table 2.

This table contains a scale value for only thirty-four zones, as information on the average value of structure was not available for seven zones. These unscaled zones were smaller in size but were scattered through the community so that the remaining thirty-four would appear representative of the total geographic range of the community. From Table 2 almost two-thirds of the zones appear relatively homogeneous and one-third appear relatively heterogeneous. Thus it might appear that it is possible to have reasonable confidence in the representativeness of the averages used to describe the attributes of the zones. The fact that many zones are not relatively homogeneous is found in most cases of community research in which local areas or tracts are selected as units of analysis. There are few cities in which some neighborhoods are not characterized by mixed land uses and mixed populations.

Especially this condition is true when areas of a city are undergoing change in land use. In the case of the Champaign-Urbana survey, the effort to ensure homogeneity of zones resulted in defining a number of zones so that they contained rather small populations. However, as Table 2 indicates, most zones were, in terms of selected socio-economic attributes, relatively homogeneous.

C. CONTROLLING FOR "ECOLOGICAL FALLACY" IN STATISTICAL CORRELATIONS

Once the zones with a non-student population had been selected and their degree of homogeneity determined, the next concern was the choice of indices of these zones which were to be utilized in the analysis. It has already been noted that the original plan of analysis called for the use of measures of statistical correlation, for example, coefficients of correlation and factor analysis, to indicate or to suggest the socio-economic influences in traffic generation. The decision to use survey zones as the primary units in the study means that the statistical correlations which are derived from correlating indices of survey will be "ecological correlations."(7,8)

The "ecological correlations" of the present study were correlations of groups of households represented by the zone averages of household characteristics computed by survey zones. The variables used in the correlations were not properties of specific households themselves such as owning or not-owning a vehicle, but rather properties of a group of households such as the proportion which own vehicles or the estimated average value of residence. Robinson and others have shown that error, normally in the form of spuriously increased coefficients of correlation between traits, can occur if the actual statistical correlations are made in terms of ecological variables representing groups rather than in individual units. With respect to the present study such an "ecological fallacy" could possibly occur if a coefficient of correlation were computed between the average occupational level of households by zone and the average number of vehicular trips of household by zone.

Various procedures can be used either to guard against or to detect ecological fallacy in a study. In this case an ecological unit, the survey zone, was defined as the primary measure of traffic generation. The decision to use survey zones rather than separate households as the basic analytic unit was based on the grounds that traffic, from the very nature of the roadway system, represents vehicular movement between geographic areas or zones within a community. The problem in detecting ecological fallacy was in determining whether survey zones described in terms of household traits met the necessary conditions. Two conditions which may increase the possibility of ecological fallacy concern (1) the heterogeneity of the ecological units, in this case the survey zones, and (2) the source of variance in the dependent variables in the ecological correlation. In respect to heterogeneity, the data of Table 2 show that most of the survey zones appear to be reasonably homogeneous in respect to socio-economic variables which are pertinent to the study. This fact suggests that measures such as means and percentages of the survey zones will not reflect excessively the so-called ecological fallacy.

A second test for detecting the influence of this fallacy is to examine the source of the variance in one of the significant variables to ascertain if this source is primarily within the units constituting the universe of the study or if it is distributed throughout the whole universe. For example, in the present study, is the variation in the major dependent variable, the measure of vehicular traffic, found primarily within the survey zones themselves, or does it represent largely variations between survey zones? If it is the latter case, then survey zones would appear statistically to be primary units in the generation of traffic volume, and it might be possible to predict traffic volumes from the characteristics of zones without being subject to the ecological fallacy. One way of testing this possibility is to make an analysis of variance of the relation between the average number of vehicular trips for each of the survey zones and some other average index of each zone which is known to be typically a good predictor of number of vehicular trips. Such a predictor trait is the number of vehicles in the community, an item which a series of studies have shown to be the one trait which is consistently most highly correlated with the number of vehicular trips. (When the zero-order coefficient of correlation between the average number of vehicles per household and the median number of trips for the forty-one selected survey zones is computed, its value is 797.) This type of test is developed in Table 3.

This table shows that the amount of variance associated with the estimated relation between the median number of trips and the average number of vehicles by zone which can be attributed to differences between the survey zones is about 2-1/3 times that which has its source within the zones. Furthermore, this finding is quite unlikely to be a result of chance. The fact that this proportion of the variance associated with an estimated relation between vehicular trips and another index has its source in differences between zones suggests that this zone trait actually measures a household characteristic in which zones differ significantly. Had the findings of Table 3 shown that the variance about the regression line of the coefficient of correlation had equal sources within the zones and between the zones, there would have been some question as to whether social factors influencing traffic generation are properly described by zone averages.

D. HOUSEHOLD CHARACTERISTICS ASSOCIATED WITH TRAFFIC GENERATION

The findings of Table 2 and 3 suggest that the ecological fallacy is not, as far as these tests indicate, likely to lead to spurious correlations in the statistical estimation of the relation of household traits averaged by zone to volumes of traffic averaged by zone. Therefore, it appeared proper to correlate the items presented in Table 1 using the zone averages for these measures. The purpose of this new computation of correlations was to see if it changed the previous association to a significant degree. A number of items for which data was not available on the original number 1 and number 2 cards of the household survey were added to the matrix of items to be correlated. These items had been compiled from various sources after the original computations of coefficients of correlation. They were the median age in years of vehicle, the estimated value of the vehicle as defined by make and style, and the value of the residential structure as estimated by a project studying real estate values in the Champaign-Urbana community. These items were added to the original matrix of correlations and the new matrix of coefficients of correlations is shown in Table 4. This table also contains an additional item, "coefficient of variability," which pertains to the value of the residential structure. This item was used in the measure of homogeneity of zones reported in Table 2. As a measure of traffic generation, the "median number of trips" by all households for the zone was used for the zone measure of central tendency in trips by household because of the remarkably skewed distribution of trips by zones which ranged in number from approximately one to thirty.

Examination of Table 4 indicates that the principal consequence of computing the coefficients of correlations by zone averages is to raise the level of the coefficients originally expressed in Table 1. The new items added to the matrix did not show appreciably high correlations with trip generation. They did, however, show some statistical association with one another. Significant differences between Tables 1 and 4 can be summarized by comparing the coefficients of correlation of the items in Table 1 Item 7 with the number of trips with the same items in Table 4 Item 15. The results of such a comparison are shown in Table 5, which also includes the increase in explained variance for these items in the six of seven cases where such an increase occurred.

Table 5 indicates that for all items which showed an appreciable coefficient of correlation with trip generation at the household level, there was a considerable increase of these coefficients when the survey zone averages were used for computation. The greatest increase was for the item "number of vehicles in the household," and there was a slight decrease for the item "length of residence of household," but the latter showed practically no association with trip generation. In order to summarize the findings in Table 5, the items were ranked by size of correlation coefficients as computed by both the household and survey zone measures. The results of this step are shown in Table 6.

The data in Tables 5 and 6 are instructive of the consequences of computing correlation coefficients from zone averages based on household traits instead of household traits themselves. First, when the size of the correlation coefficient of an item with the number of trips made by a household is compared to the size of the coefficient computed from an index of a survey zone, in all cases but one there is an increase in the size of the coefficient. Examination of the comparative rankings of these coefficients for the two computations shows, however, that there is not an appreciable change in rankings. It would seem, therefore, that computing correlations based on survey zone averages rather than on separate households increases the value of correlations, but does not produce an appreciable change in the rank of association of items with measures of traffic generation. In other words, the items which are strongly correlated with vehicular trips production by households show a parallel correlation with items measuring these same traits averaged by survey zones. This fact seems to confirm the basic research strategy of the study: to treat the household as the fundamental unit which generates traffic and to regard household traits summarized or averaged by survey zones as independent variables to be correlated with measures of trips by zones.

E. GROUPING SURVEY ZONES FOR ANALYSIS

The fact that grouping households by zones generally increases the amount of variance explained by correlating household traits with number of trips suggests that, perhaps, grouping of zones themselves might further add to the amount of explained variance involved in the association of household traits and traffic. Unfortunately, the number of zones utilized in the Champaign-Urbana study was so small that any inclusive combination of them containing enough zones and the chances of their appearing in numbers large enough to be appropriate for regression analysis based on coefficients of correlation did not appear feasible. Still, it did appear that some larger consolidation of zones for the purpose of analyzing the association of these groupings with production of trips would be worthwhile to a study of socio-economic factors in traffic generation. It had been demonstrated that the number of vehicles was an item closely linked with trip generation. Therefore, it seemed likely that groupings of zones which were contiguous and roughly similar in vehicle ownership might give larger units distinctively associated with traffic generation. An approach such as this had been used in the Chicago Origin-Destination Survey through the use of a series of rings concentric to the CBD with the areas in each ring roughly equidistant from the CBD. The Chicago study revealed important differences by these rings in regard to aspects of traffic generation and to characteristics of their populations. Thus, such a procedure appeared justifiable with the zone data of the Champaign-Urbana study, although it could not be related directly to the correlations obtained with traits at the household and survey zone level.

The present study could not replicate exactly the procedure of the Chicago study partly because the Champaign-Urbana CBD is bi-partite, as defined in the survey, and because the shape of the community is more elliptical than circular. Also, a sizeable area on the southern perimeter of the community consists of the property of the University, and it does not show the pattern of land use and residence normally expected for an outermost segment of the area of a smaller city. As a result of these conditions, it was difficult to construct a set of rings made up of survey zones equidistant from the CBD as was done in the Chicago study. It was possible, however, to make rings consisting of contiguous survey zones which were roughly similar in respect to the proportion of non-student households containing vehicles. Since the number of vehicles in a zone had been integrally related to the production of traffic by the zone, it was assumed that rings calculated in this fashion would show homogeneity in potential for traffic generation. When the three rings which this technique yielded were plotted on a map, Figure 2, it was apparent that the average distance from the CBD of the zones making up each ring was clearly different from the other rings. The pattern of contiguous zones roughly equal in proportion of households with vehicles was then plotted on a base map, and three major groups of zones were revealed as shown. These groupings are roughly concentric to the bi-nodal CBD; hence, it was decided to label them Rings I, II, and III. Household and traffic-generating characteristics of each of the rings were calculated by consolidating data for the survey zones making up each ring with the results shown in Table 7.

This table shows certain clear-cut differences between the rings in respect to household and traffic characteristics as well as in location. Parts of Ring III are obviously the greatest distance from the CBD, and Ring I zones, on the average, are closest to the CBD. The rings do not produce vehicular trips proportionate to the number of households contained in them. Column 7 shows clearly that when all households are considered there is marked difference in the average number of trips per household. This finding is in agreement with those of the Chicago study, however, it appears to result from the fact that Ring III contains the highest proportion of households possessing vehicles. When the number of vehicular trips per households possessing vehicles is figured, the averages per ring are more nearly alike and there is no clear pattern of differences in rings by distance from the CBD. In fact, Column 8 seems to suggest that the average number of trips per vehicular-owning household are remarkably similar when compared by gross geographical groupings such as these three rings. If such a condition were actually the case, trips per vehicle household would show little variation by the spatial classification used in an analysis. Thus, it would seem that a study through this approach would contribute little to understanding socio-economic factors in traffic. One condition which seems to be operating here is that with an increase in the size of geographical unit used to measure household and traffic attributes, the unit becomes heterogeneous in respect to these traits. In such an instance it becomes more difficult to pin-point the influence of variables on one another.

It appeared from the data in Figure 2 and Table 7 that viewing the conditions of household traffic generation from a larger geographical base than the survey zone would not contribute to analytic understanding of the relation between the socio-economic attributes of households and traffic generation. The conclusion drawn from the various findings presented in this chapter is that indices based on the survey zone itself are apparently the best device for analyzing this relation.

F. SUMMARY

The problem treated in this chapter was the choice of the basic unit of analysis to be correlated with traffic generation. Alternatives included separate households, survey zone, or some combination of survey zones. For practical reasons it appeared in the study that some type of geographical area would have the most utility, because traffic volumes represent flow of vehicles between grographic areas linked by the roadway system. Non-student household data was separated from student households and the analysis was limited to the former items. Forty-one zones were selected for analysis, and they were examined with respect to socio-economic attributes of households in order to determine the degree to which averages or other summarizing indices actually represented zone populations. By a method of scale analysis it was calculated that approximately two-thirds of the zones were reasonably homogeneous by these socio-economic measures.

Also treated in this chapter was the problem of using zone averages rather than traits of separate households which might lead to an "ecological fallacy" involving spurious correlations. The fact of relative zone homogeneity and the finding that the main source of the variance in the regression relation between number of trips and number of vehicles was between zones, and not within zones, suggested ecological fallacy would not be a major consideration. The ranking of size of correlation between vehicular trips and other household traits was almost the same as computed for households separately and for survey zones.

By grouping contiguous survey zones which were similar in the proportion of households owning vehicles, it was possible to delineate three types of geographical location, or rings, which varied considerably in average traffic generation by all households in the ring. These differences appeared attributable to proportions of households owning vehicles; the average number of trips per vehicle-owning household appeared almost constant by the three rings. However, each ring displayed considerable internal heterogeneity in household characteristics and, therefore, the rings did not appear to offer as adequate categories as zones for analyzing the relations of household traits to traffic generation. The findings developed in the chapter suggest that the statistical correlation of zone averages of household traits with measures of traffic generation is technically correct and would give results pertinent to the aims of the study. •

IV. THE RELATION BETWEEN HOUSEHOLD CHARACTERISTICS AND SELECTED MEASURES OF TRAFFIC GENERATION

A basic assumption of this study was that vehicular trips in an urban community are in a large part initiated within households and that variations in characteristics of households might be associated with variations in rates of traffic generation within a community. The last chapter has indicated ranges in rates of traffic generation in areas of Champaign-Urbana and has proposed that indices of households summarized by the survey zone are useful measures for statistical correlation with estimates of traffic. This chapter describes the range of traffic generation which is statistically associated with households, and explores certain statistical relations between characteristics of households and measures of traffic.

Previous studies of the generation of traffic have indicated that the number of vehicles in a community is highly correlated with the number of vehicular trips reported for that community and that the number of vehicles located within a sub-area of a community is highly correlated with the number of trips reported as generated by the same vehicles. The findings of the present study, as noted in the previous chapter, indicate that the average number of vehicles per survey zone correlates reasonably well with the average number of trips produced per survey zone. All of this evidence seems to indicate that it is the number of vehicles and households which is crucial to the production of trips within a community. In one sense, however, vehicle ownership by the household is only an intervening variable in the production of trips by these households. The fact that a vehicle is located in a household does not in itself account for the degree of use of the vehicle; rather, it is presumably some other distinctive characteristics of households which are associated with the decision to utilize the vehicle.

A. NUMBER OF VEHICLES PER HOUSEHOLD

The exploration of the differences and likenesses both in socio-economic characteristics and in traffic generation of one- and two-vehicle households is revealing of factors entering into community traffic. Table 8 suggests such factors.

The data of Table 8 supply some basic information on the association of vehicles and households as reported in the household survey. Roughly about 15 per cent of the households interviewed do not have a vehicle and about the same ratio have two vehicles. The 70 per cent of households having one vehicle generate, as might be expected, fewer vehicular trips per household than do two-vehicle households. It is noteworthy, however, that the average number of trips per vehicle for two-vehicle households is almost one-third less than that per vehicle for one-vehicle households. In other words, an increase in vehicles per household does not proportionately increase traffic generated by those households. This finding is significant for the strategy of research involved in the present study which is seeking to correlate traffic generation by geographic area with summary indices of the households in the area. This correlation obviously can be confounded by variations in the ratio of two-vehicle households in a zone. Moreover, this finding suggests that future increases in the number of vehicles in a community may not proportionately increase the number of vehicular trips in the community, if the increase in vehicles represents predominately an increase in the number of two-vehicle households.

Another important aspect of the results shown in Table 8 concerns the proportion of all vehicular trips which represent trips made involving only the driver, and the proportion involving driver and passengers. Approximately two-thirds of all vehicular trips involve only the driver, and the remainder the driver with passengers. This suggests something of the habits or customs of vehicular use by members of the household which the present study sought to explore further. It was hypothesized that the number of driver-only trips would be more clearly characteristic of two-vehicle households because the presence of two vehicles would facilitate the individual use of vehicles by household members. The data in Table 8 did not confirm this assumption since there is barely a 3 per cent difference between the two kinds of households in respect to the proportion of all vehicular trips made involving drivers only. This finding suggests that the general pattern of household use of vehicles is very similar between one- and two-vehicle households despite the appreciably greater generation of trips by two-vehicle households. The suggestion seems to be that there is a basic household parameter in the ratio of collective to individual use of vehicles in one- and two-vehicle households.

B. PASSENGER TRIPS PRODUCED BY HOUSEHOLDS

The total participation of members of households is, perhaps, best measured by the total number of household members who become involved in trip-making either as drivers or passengers. Table 8 is based on the unit of vehicular trips, and these findings should be supplemented with information on the range and distribution of passenger trips by households. Especially is this kind of information relevant in understanding the significance of measures of central tendency such as the arithmetic average or median of distributions of trips by households when these measures are used to describe the traffic production of a population of households or are used as variables correlation procedures. In the subsequent analysis represented by Table 9, drivers without passengers are classified as passengers. This table represents the distribution by number of passenger trips made by one- and two-vehicle households.

The data in Table 9 provide important findings relative to the range in number of passenger trips made by households and to the significance of measures of central tendency as they describe the distribution of this range for both one- and two-vehicle households. The table reports the total number of passenger trips recorded in the household survey during the previous twenty-four hours of the day on which the interview was held in the household. The number of trips ranges from 0 to 40 per household. The trips are presented as proportions of all trips one- and two-vehicle households as made by the households. Columns 3 and 5 show the per cent of all families in the one- and two-car categories which made this number of trips.

A striking characteristic of the distribution in all columns is the distinct skewness upward in respect to number of trips made. This tendency is clearly indicated by the fact that the median and mode of per cent of households making the total number of trips both fall well below the arithmetic average of this distribution. This suggests that the use of the average, or arithmetic mean, of the number of trips per household is a rather poor description of the central tendency of the range of the total distribution of passenger trips by household. The skewed distribution of trips also raises questions concerning the reliability of findings involving statistical correlations, since the formulae for these findings presume a normal distribution of the variables being correlated.

One way of stating this discrepancy from normality of the distribution is to note that the lowest ranking 40 per cent of the one-vehicle households account for barely 15 per cent of all passenger trips; whereas, the top ranking 15 per cent of one-vehicle households account for almost 40 per cent of trips. Such a distribution is anything but normal especially when, as is the case with one-vehicle households, it appears to be continuous. The two-vehicle households demonstrate a similar pattern, but it is more difficult to estimate their basic distribution because there are several discontinuities in the graph of their numbers by class intervals. This tendency suggests that two-family households may consist of several populations in respect to characteristics involved in the generation of passenger trips, or it may be the fact that two-vehicle households constitute such a numerically smaller sample than one-vehicle households that estimation of a true distribution is subject to sampling error in this case.

It is possible that the information in Table 9 may give some clue as to the point in household passenger trip generation at which households move from one-vehicle to two-vehicle households. This point would seem to be the class interval where the percentage of one-vehicle household trips is greater than the percentage of one-vehicle households making this number of trips, and the percentage of two-vehicle households trips is less than the percentage of two-vehicle households making this number of trips. There are two such intervals, 7-8 and 9-10. It would appear, then, that somewhere within the range of 7-10 passenger trips for the one-vehicle household the pressures of trip generation by household members are such as to encourage the acquisition of a second vehicle. At least, beyond the level of 10 trips per twenty-four hours, the two-vehicle households consistently show a larger proportion of all household trips in these class intervals. Only slightly more than 20 per cent of one-vehicle households make more than ten trips per twenty-four hours, while about 40 per cent of two-vehicle households do. These one-vehicle households, however, account for 50 per cent of one-vehicle household passenger trips; whereas, these two-vehicle households account for barely two-thirds of two-vehicle household passenger trips. There is the suggestion here that the use of vehicle in two-vehicle households is less intensive and less organized than it is in the single-vehicle households which are high generators of passenger trips. One reason for this condition, which will be examined in a later section, is that some single-vehicle households apparently carry an above average number of passengers on vehicular trips.

This tendency is most pronounced in the Ring I survey zones of Figure 2. Instead of securing an additional vehicle, these households apparently intensify the use of the single vehicle. The evidence will also suggest that adding a second vehicle is characteristic of households at the higher socio-economic level.

The reservations suggested by analysis of the information in Table 9 must be kept in mind while interpreting the results obtained by correlations of averages of household characteristics by survey zone with measures of traffic. Such statistical correlations, however, seem to be necessary to obtain some underlying connection between traits and the utilization of vehicles by households. A number of measures of households were constructed, some average by survey zone for these measures was determined, and kinds of correlations between measures of traffic was made.

C. PASSENGER TRIPS AND HOUSEHOLD CHARACTERISTICS

At the beginning of the study there was no well-defined expectation as to which characteristics of households would show clear-cut association with trip generation other than the number of vehicles by household per zone. It was, therefore, decided to develop information by survey zone on as many items as possible which were descriptive of households and which might possibly be related to or serve as predictors of traffic generation. These items were then factor analyzed to determine if there were patterns of associations of any of the items with traffic generation, and from such associations, if any, correlations could be computed to suggest household traits linked to traffic.

Twenty-six items which could be summarized by survey zone data were selected, as were three measures of traffic generation. Most of these items represented data secured through the household survey or information contained on the number 1 card for households and number 2 cards for trips. One item, "average value of structure," was secured independently of the survey. It represented the findings of another research project on traffic which had analyzed the market value of residential structures in various survey zones of Champaign-Urbana. Several items called for computations involving the number of acres in each survey zone, and these figures had to be secured independently of the survey information. The entire set of items is listed in Table 10.

More detailed definitions of Items A, 1-26 are found in Appendix B along with the range in value of the items by zones. The measures of Items 1, 25, and 26 are values of scales which were constructed from the survey zone data. Appendix C indicates the procedures used for the scales.

Once the items had been selected, they were used for two factor analyses on the data of all reported trips. One such analysis was of those trips in which the vehicle contained only the driver, and the other analysis was for trips on which the vehicle contained the driver and passengers. The purpose of the two factor analyses was to ascertain, if possible, whether there were discernible patterns of characteristics which distinguished trips with passengers from those which generated trips with only the driver. If such differences could be discovered, they might serve to explain some of the underlying dynamics of household utilization of vehicles.

If any measure of traffic appeared as a high loading on a factor, it would suggest that it was significantly associated with the other items. If a measure of traffic generation did not appear as a significant item among the loadings, it still might be possible to identify other patterns of characteristics involving drivers, households, or zones themselves which might suggest socio-economic influences on trip generation. With these purposes in mind, the two factor analyses were computed. The same household could be represented in both sets of averages if it produced both kinds of trips. It should be noted that the number of cases in which the two factor analyses were made is unusually small (41), the number of zones for which the averages were available. It, therefore, seemed that only a few factors derived from the list of twenty-nine items factored would be unequivocal in meaning. The factor analysis was done on the Illiac computer of the Digital Computer Laboratory of the University of Illinois using the varimax program. The program called for a centroid solution with fixed communalities rotated to ten orthogonal factors. Appendix D contains the table of rotated factors for the two solutions. However, before turning to a discussion of the factors revealed by the solutions, some attention should be given to the means and standard deviations of the list of items noted in Table 10.

Comparisons can be made between the averages of these items on the two populations. The averages and standard deviations, computed from the zone averages on these two kinds of trips, are shown in Table 11.

Examination of this table shows, in general, a remarkable similarity between the two populations in respects to household traits. Such a similarity suggests that the same households generate both kinds of trips and that there is not a large proportion of zones which mainly produce trips with driver only or with driver with passenger. It might, therefore, be expected that the factors identified through the factor analysis of the data for each of these populations will be relatively similar. There are, however, several minor but interesting distinctions between the two populations of trip-makers in terms of trait averages. First, with respect to trip purpose, vehicles containing only the driver are more likely to be making trips for work or business, while vehicles containing passengers are more likely to be making trips for purposes other than work or business. Also, the size of the standard deviations indicates that vehicles with passengers show a greater range of purpose than those with the driver only. Second, the age of drivers without passengers is about seven or eight years greater than that of drivers with passengers, and this difference even allowing for the large standard deviation, is significant at about the 10 per cent confidence level. Third, the average number of passengers (including the driver) is only slightly more than two, and there is a relatively low standard deviation for this item which suggests that vehicles do not generally contain more than two persons. These differences in a general way are informative of tendencies and habits of households with regard to the utilization of vehicles. It might be expected that some of these items which reveal these tendencies might appear as components of the patterns to be revealed by factor analyses.

Finally, two descriptive statistics of interest found in Table 11 are: first, that the median age of vehicles is slightly more than five years, and second, slightly more than 50 per cent of potential trip-makers make trips in the course of a typical twenty-four period. The standard deviation of this last statistic is large, and, as will be noted later, the range in this measure appears highly correlated with the range in trips generated by zones. Table 11 indicates that the characteristics of households which generate trips with the driver only and those which produce trips including passengers do not, with the present measures, reveal significant clues concerning the socio-economic influences of household traits on trip production.

One final note is suggested from comparing Tables 8 and 11 as to the average number of passengers per vehicular trip. Table 8 shows that two-thirds of reported vehicular trips involved the driver only. Table 11 indicates that the median number of passengers (driver included) for vehicular trips involving more than one person was approximately two persons. These data, therefore, indicate that on the average there would be roughly 1.3 persons per vehicle as computed from the reported trips. This figure is slightly less than the figure of 1.5 persons for internal trips given in the official summary of the Champaign-Urbana survey.(9) This difference is small, but it suggests that the methods of computation utilized in the official report and in the present study may have varied. The important point to consider is that any average of passengers trips drawn from a universe in which two-thirds of the cases involve only one passenger, the driver, is a relatively poor measure of the central tendency of this universe. This issue has been previously raised with reference to the remarkably skewed distribution of many statistics of traffic generation, a condition which may reduce the significance of arithmetic means as descriptions of these distributions.

D. FACTOR ANALYSIS OF TRIPS AND HOUSEHOLD CHARACTERISTICS

The factor analysis of these two types of trip producing populations is more informative. The factor loadings on all computed factors from the two analyses are shown in Appendix D, and the selected loadings on the first five factors are shown in Tables 12 and 13, which also indicate the per cent of variance attributable to each factor.

The basis of identification and the grounds for interpretation of the factors suggested by Tables 12 and 13 will follow, but as an introduction to this discussion there should be brief comment on the technique of factor analysis as it is applicable to this study. As a device for discovering patterns of associations among items making up a broad set of observations, a factor analysis begins with a matrix of zero-order, product-moment correlations between a number of variables such as that represented by Table 1. Through a number of mathematical manipulations performed on such a matrix, sets of discrete variables whose relations had previously been stated through correlation coefficients are each discovered to contribute in common to the total variance represented by the correlation matrix. A set of items which together contribute to the matrix variance are called a factor and are assumed to have some property in common, at least, as it may contribute to the observations which are recorded in the matrix of correlations. By means of factor analysis, it is, therefore, possible to reduce a large number of variables to a smaller number of sets of variables which represent more general elements or factors in the total group of statistical relationships existing between all the items involved. Such a reduction of variables may give some understanding of or clues to the relationships among a diverse set of items.

In the present study a set of items would be the relationships represented by the zero-order coefficients of correlation of all the items in Table 10 with each other item. Some of these correlations were already expressed in Table 4, but the actual matrix of coefficients of correlation constructed for the two factor analyses was of the inter-correlations of all twenty-nine items of Table 10. Item 10 of Table 10, "Median number of persons in vehicle," was dropped from the analysis because it was always one. The number of cases for the correlations for each matrix were forty-one, the number of survey zones for which the measures of the items in Table 10 for which zone averages or summaries were available. According to the criteria used by some authorities, this number of cases is relatively small, to be certain that the variance about the total set of inter-relations is randomly distributed. In a situation such as this, a more cautious interpretation of the findings from the factor analysis is recommended.

With this caution in mind the following procedures were utilized. The matrix of the product-moment correlations between the items of Table 10 was solved for ten factors by the "centroid" method and then rotated to an orthogonal solution. This last step gives the "loading" for each variable on each of the ten factors. Loadings represent the extent to which the particular variable under consideration correlates with the variance which can be attributed to the whole set of variables making up the factor. Only variables which have "high" loadings on the factor are regarded as constituting the factor. In this study a value of approximately .50 or higher was regarded as acceptably high loading.

The number of factors which will be identified is not normally known at the start of the factoring procedures. In the present study it was assumed that the number of factors would not be more than one-third of the number of items contained in the inter-correlation matrices of the items in Table 10. For this reason the original solution was for ten factors. A factor is meaningful for a study if it accounts for appreciably more of the variance contained in the matrix than does an average item in the matrix. For example, an item among the twenty-nine variables in Table 10 would probably account on the average for a little more than 3 per cent of the total variance. If a factor representing a set of several items does not account for considerably more variance than this amount, it does not offer an analytic contribution much beyond that of a single item itself. The amount of variance attributable to the ten factors in each of the two factorings are shown in Tables 12 and 13, respectively. The complete set of loadings for all variables is shown in Appendix D, while only those above the criterion of approximately .50 are contained in Tables 12 and 13.

E. INTERPRETATION OF THE FACTORS FOR TRIPS WITH DRIVER ONLY

The utility of factor analysis in interpreting bodies of data depends upon factors representing variables which have some self-evident attributes which link them together as explanations of the variance discovered through the correlation of the variables. To some extent this condition holds in interpreting the findings of Table 11. Factor A which accounts for 22 per cent of the variance shows high loadings on most of the measures of traffic generation. This indicates consistency between these measures. It appears significant that two clear-cut indices of socio-economic class level, occupations and socio-economic type of survey zone, are part of this complex of loadings. It might be expected that the value of residential structure would appear as part of this complex, but, unfortunately, the value of structure used in the scale represented both single and multiple family dwellings. Apparently, multiple dwellings including apartment houses are low generators of traffic, since this item shows a negative loading on this factor. The age of the vehicle seems to bear some relation to this complex, as its loading is almost at the criterion level. Make of vehicle, however, is not part of this factor, apparently because some of the low traffic generating zones contain used and older more expensive makes of vehicle. The impression gained from the make-up of Factor A is that it is a traffic generation factor linked to socio-economic factors and amount of traffic generation. The fact that indices of traffic generation are the major dependent variable makes reasonable the finding that this variable accounts for the highest proportion of variance.

Factor B shows high loading on the purpose of trips from the home and the purpose completed prior to trips to home. The household characteristics which cluster with these variables are age of the driver and the length of residence. The factor appears to imply that older drivers who have lived longer in the community leave home for purposes of work or business and return home primarily from having completed these purposes. It appears significant that purpose, at least for some types of trips, is independent of the amount of traffic generation, and that purpose should be most closely linked to older age and longer length of residence. The implication would seem to be that these types of drivers have a more structured pattern of trip-making than other segments of the population.

Factor C contains only two items at the criterion level of loading. This paucity of associated variables makes it difficult to interpret the factor since the nature of the two items do not suggest any obvious common property. One item is the time of the trip during the afternoon, which in this factor is to the home, and the other element is the distance from the CBD of the survey zone. The combination suggests that the greater the distance from the CBD, the earlier the afternoon trip to home is made. The meaning of such a factor is not self-evident, but several of the highest loadings below the criterion level suggest that conditions which may be operative. These secondary attributes include a lower rate of passenger trip generation, a lower rate of trips per developed acre and lower homogeneity of survey zone as measured by type of vehicle and variation in value of the residence. This factor appears to be a time of trip complex associated with greater distance from CBD and lower trip generation of zone. The basis for such a pattern of associations is not clear, but it does appear significant that the time of the trip emerges as an element of a major factor.

Factor D does not appear to involve any measures of traffic as important variables. This fact, in itself, is noteworthy as it demonstrates that factor analyzing an array of data such as this does not necessarily produce statistical patterns which include items pertaining to traffic. This factor seems to involve the qualities of large-sized households who live in residential structures of low value. Higher loadings on a number of secondary items suggest that this factor involves a lower occupational level, a lower ranking of survey zone by socio-economic type, and lower-priced makes of vehicles. In short, it is a complex of items representing households which are low in the socio-economic scale. In other words, the lowest socio-economic status of households appears neutral to any aspect of traffic generation. It might appear that the relation between amount of traffic generation and socio-economic status is discontinuous at the lower socio-economic levels.

These four factors are the only ones containing loadings on constituent items of approximately .50 or higher. For this reason they are the only factors considered in identifying constellations of household traits which might be linked with traffic indices. The first three factors contain traffic indices as constituent elements, and the four factors account for about 55 per cent of the variance contained in this array of data which represents the inter-relations of household traits and traffic indices for trips involving the driver only. Two conclusions may be drawn from the identification of these four factors: (1) higher socioeconomic status of households shows the highest association with measures of traffic; and (2) the influences which operate on traffic are either varied or diffuse in their action, for the most clearly identifiable factors account for barely a majority of the total variance in this set of relations.

F. FACTORS IDENTIFIED WITH VEHICULAR TRIPS INVOLVING DRIVER AND PASSENGER

The same procedure for identifying factors was applied to the matrix of correlations for vehicular trips involving more than a driver. The purpose of this step was to determine if the factors previously identified were also characteristic of both types of vehicular trips. If such a result could be demonstrated, it would suggest general or universal tendencies by households in their traffic-producing patterns. Actually, the comparison of the item loadings in Table 13 to those in Table 12 indicate several differences in respect to the identifiable factors. These differences can be seen from following the list of four factors suggested by Table 13.

Factor A appears identical to the A factor of Table 12. This factor is traffic generation linked to high socioeconomic level of household. In Table 13 it accounts for most of the variance of the set of relationships, and it appears to be a general and primary factor in the relation between household traits and traffic indices. Factor B in Table 13 is slightly different from the same lettered factor in Table 12 since it shows a heavy loading on both time and purpose indices. It suggests that for trips to home where the driver is a long-time resident, the departure from home in the P.M. is earlier. The suggestion here is that having a passenger introduces the time variable as part of the factor. Factor C appears, at first sight, to be a household trait factor. It suggests that the younger drivers in lower-priced makes of cars are associated with larger sized households. Secondary high loadings suggest further that these drivers are white males, living in zones at a considerable distance from the CBD where there is relatively low residential density. This factor seems to be the reverse, in some sense, of Factor B from

Table 12, in which older age is an attribute of driver only trips. Younger drivers from larger households, by contrast, are associated with trips with passengers.

Factor D shows only one critically high loading which makes it a somewhat difficult factor to interpret, especially since this loading suggests that the pattern involved represents a tendency for persons who make trips to make only a few trips. The secondary loadings give some further intimation of other household traits involved in this pattern including a high number of persons in the household making trips while the household itself does not make many vehicular trips. The loading on occupation also seems to imply a somewhat lower economic level of households. The total factor, then, appears to represent a tendency of households containing a larger number of persons to make passenger trips with a limited number of vehicular trips. Such a pattern is obviously that of multi-passenger trips, and it is apparently more characteristic of lower socio-economic levels. Moreover, this factor is certainly one which would be expected to appear from the data of trips involving driver and passengers, and in this sense is a confirmation of the validity of the method of factor analysis to determine patterns of household characteristics associated with measures of trip generation.

These four factors account for approximately 55 per cent of the variance involved in the intra-correlation of the items defining trips involving the driver and passengers. The factors, however, appear somewhat different from the set associated with trips involving the driver only with the exception of the first factor, which under both conditions shows a clear pattern for a higher occupational and economic status to be positively associated with amount of trip generation. The analysis of the information on attributes associated with trips involving passengers indicates also that the influences on trip generation are varied and presumably diffuse since the statistically most important factors account for barely a majority of the variance involved in the intra-correlation of these attributes. Time of trip and purpose of trip emerge as characteristics of trips which are related to characteristics of households. The number of trips, however, is the attribute of traffic which is most clearly related in any case with household characteristics.

Yet, it is obvious that trips involving passengers reflect different influences and are associated with different traits of households than are trips with drivers only. What is of particular interest is the suggestion contained in Factor D that multiple passenger trips are linked to an increase in the proportion of members of households who make trips but this does not necessarily imply an increase in the average number of vehicular trips per household. Findings such as this suggest something of the dynamics of decision-making in households relative to the use of vehicles for trip purposes. Of course, it should be kept in mind that since about two-thirds of all vehicular trips contain only the driver, that the explanation of or prediction of volumes of vehicular traffic will depend mainly on discovering characteristics associated with driver-only trips. The use of the technique of factor analysis as described above has suggested such associations.

G. MULTIPLE CORRELATION BETWEEN VEHICULAR TRIPS AND HOUSEHOLD TRAITS

The factor analysis has shown that trip generation is most closely linked to occupational and economic household traits. This relationship can be expressed as a coefficient of the multiple correlation between the average number of trips per zone and other zone averages of occupational-economic level of household. Such a multiple correlation would also serve as a prediction of how much a combination of household traits would generate traffic. Furthermore, multiple correlation would show the relative contribution of each of the traits to the variation in the predicted variable, in this case average number of trips per zone.

The formula for the coefficient of multiple correlation in this instance is not only a prediction of the number of trips which can be generated under certain conditions, but it can be a device for understanding the factors or influences which enter into trip generation. One of the aims of this study was to identify such factors for which information or measures were available through sources other than origin-destination surveys. Certain of the items in Tables 12 and 13 which are shown to be related to trip generation might well serve as such measures. These items were, therefore, converted to the independent variables of the formula for a coefficient of multiple correlation as shown in Table 14.

The findings of Table 14 are instructive of the variables associated with trip generation in a city such as Champaign-Urbana. Three of the variables R_2, R_3, and R_4 contribute approximately the same amount of statistical influence to variation in the dependent variable. Two of these variables are strictly socio-economic in nature: level of occupation and price of make of car. Both indices are positively associated with increase in trip generation as might be surmised from the nature of Factor A in both

Tables 12 and 13. The variable R_3, value of structure, shows a negative correlation with trip generation because the most expensive structures were multi-family dwellings or apartment houses whose inhabitants either did not own a vehicle or used it less. The difference in value of residential structure is, therefore, a variable which does not reflect differences in socio-economic level as much as it reflects differences in types of households or families found in apartments and non-apartment residences. Apartment house families tend toward fewer members, more older persons, and fewer children. In this community they were less likely to generate trips than households living in single-family residences, which was the prevailing mode of residence. The fourth independent variable, distance from CBD, was included because in other studies of traffic generation it was highly correlated with trips. In this situation it clearly is not as important as other variables. This condition may have resulted from the bipartite pattern of CBD in Champaign-Urbana. A primary conclusion, however, which can be drawn from Table 14 is that trip generation is definitely correlated with the socio-economic aspects of and the types of family and households to a greater degree than is the location of the household relative to its distance from CBD. Changes or variations in these aspects of households in a community could be expected to have appreciable socio-economic influences on traffic generation.

It is obvious, of course, that socio-economic traits of households are not the only, or even most accurate, predictors of trip generation by households. The present study, and many earlier reports, have indicated that the proportion of households owning vehicles, the average number of vehicles per household computed by zone, or some geographic unit correlates highly with community trip generation by household. The device of multiple correlation can be applied to this basic relation between the average trip generation by household and the average number of vehicles per household. This procedure was utilized in this study with the results shown in Table 15.

The combination of the two independent variables utilized in Table 15 provided one of the highest multiple correlations of a combination of one other variable with average number of vehicles per household. The value of the multiple R in Table 15 is identical with that of Table 14. The point of interest here is the difference between the independent variables in the two correlations insofar as they help account for generation of trips by households. Table 15 seems to suggest that increases in the average number of vehicles and of persons per household in a zone will encourage an increase average trip generation by household. This relationship, however, tells very little about the nature of the households as trip-generating units. Table 14 implies that families higher on the socio-economic scale, living in single-family residences generally some distance from the CBD will generate more trips. Increases among households of these traits should promote increase in traffic generation by households.

H. DIFFERENCES IN TRIP PRODUCTION BETWEEN ONE- AND TWO-VEHICLE HOUSEHOLDS

Predicting the conditions under which there will be an increase in the average rate of trip generation by various types of households is made difficult by a lack of understanding of what kind of household activity or function trip-making is. Does the presence of a vehicle in a household generate or make possible new needs to be satisfied by trip-making, or is there a relatively fixed set of needs for trips which is independent of the availability of a vehicle in the household?

One of the sources of a partial answer to this question is the observed distributions of number of trips made over a twenty-four hour period by households. If these distributions show well-defined modalities, it would suggest that these are some norms or customs involving either efficiency or customs in respect to decisions made in the household on the use of the vehicle. Table 9 summarizes a set of such distributions. It suggests several cross-cutting tendencies among families in respect to trip generation, the most notable being the differing patterns of one- and two-vehicle households. One way of delineating these tendencies is to correlate by zones the average number of trips per household for both one- and two-vehicle households with the total zone average of trips. Such a procedure is represented by Table 16.

The data in this table shows a marked difference between one- and two-vehicle households in relation to trips generated to the average number of trips per household by zone. These differences seemed so extreme that it appeared advisable to graph the data represented by Table 16 to determine the degree to which there is such a divergence between the two types of households in their rates of trip generation. Figures 3 and 4 demonstrate the relation between the trip averages of one- and two-vehicle households and the median number of trips for households with vehicles per zone.

Figure 4 shows that there is a reasonably close linear relation between the average number of trips per zone of one-vehicle households and the median number of trips per zone of all households making trips. In this sense it appears that the trip generation patterns of one-vehicle households is typical of that of the zone. Figure 3 reveals that there is considerable diffuseness in the relation of the average number of trips per two-vehicle households to the zone median of all households. The low correlation coefficient of Table 16 appears to be mainly a product of seven markedly deviant cases among the total thirty-five zones. The remaining twenty-eight zones show a distribution similar to that of Figure 4. It is striking that six of the seven deviant cases are above average for number of trips per two-vehicle households but below average for number of trips for all households making trips.

The pattern of deviant cases seemed unusual and these zones with high rates of trip generation by two-vehicle households and low rates for the whole zone were checked on the map. These deviant zones were either CBD zones, or adjacent to the CBD and the main highways. They were zones heterogeneous in population make-up, characterized by changing land use, either residential or commercial, and by low or average rates of trip generation. The rate of trip-making of two-vehicle households obviously is atypical to that of the rest of the zone, and the zones themselves are not typical residential zones of the community. In more typical residential neighborhoods or zones the pattern of trip generation by two-vehicle households seems to represent the general trip-production pattern of the zone. These graphs suggest that zones with a relatively high proportion of households possessing two vehicles are higher economic level zones. The acquisition of the second vehicle is an aspect of higher economic status as is a higher rate of generation of trips. Apparently a large proportion of households in a zone do not acquire a second vehicle simply because there are demands for more trip generation unless the zone is in the higher economic-occupational bracket. The data indicate that a single vehicle household can generate a high rate of trips if necessary. Figures 3 and 4 suggest that zones which are homogeneous in respect to household characteristics will show a rate of trip generation which is directly proportional to economic-occupational level. Zones which are heterogeneous in respect to household characteristics will show an atypical rate of trip generation for two-vehicle households. In such cases presumably the two-vehicle households are unlike the other households in the zone in social and economic traits. This may account for the divergent rate of trips by two-vehicle households. Hence, the conclusion may be drawn that an increase average in socio-economic level of zones is directly correlated with an increase in the average rate of trip generation by household and in the proportion of households having two vehicles. Apparently, it is not the acquisition of the second vehicle itself which determines this increase in trip generation, but rather the increase in socio-economic level.

I. SUMMARY

The aim of the analysis in this chapter was to identify characteristics of households which are correlated with indices of traffic. The vehicle or vehicles in the household were assumed to be the potential for production of traffic; the traits of households were regarded as influences associated with developing this potential. A summary of the findings follows:

(1) Increase in the number of household vehicles from one to two does not, on the average, double household trip production. Approximately 70 per cent of all households are single-vehicle and about 15 per cent are two-vehicle. Two-vehicle families, on the average, only make two more vehicular trips per twenty-four hours than the single-vehicle household the average of the latter being 5.6 trips. The acquisition of a second vehicle by a household, on the average, increases the number of vehicular and passenger trips of the household by only one-third.

(2) Two-thirds of all vehicular trips by both one- and two-vehicle households involve the driver only. The one-third of vehicular trips involving passengers carry, on the average, only slightly more than one passenger.

(3) On the average, households with vehicles generated between seven and eight passenger trips per twenty-four hour period. The range in number of trips by these households for this period was from zero to forty. The distribution of cases by class intervals on this range, however, was clearly skewed upward. In fact, this skewness was such as to suggest that the arithmetic mean of passenger trips by household is a poor measure of central tendency of trip distributions. This non-normal distribution of traffic generation raises questions concerning the use of correlation statistics and analysis which assumes a normal distribution of samples that are statistically correlated. The extent of the skewness in the distribution of passenger trips is seen in the fact that the mode of passenger trips per household is approximately four, the median about six, while the arithmetic mean is closer to eight. The assymetrical quality of the distribution of traffic generation is further demonstrated by the fact that the lowest ranking 40 per cent of one vehicle households with respect to trips generated account for barely

15 per cent of all passenger trips produced by one-vehicle households. At the same time, the top-ranking 15 per cent of such households account for 40 per cent of passenger trips produced. Thus, traffic generation appears to be strongly influenced by a minority of households.

(4) It would appear that about ten passenger trips per household per day would be the normal or average limit that single-vehicle households reach before acquiring a second vehicle, or before embarking upon unusual intensive use of the single vehicle.

(5) Intensive use of vehicle is accomplished by a minority of single-vehicle households, but they generate a disproportionately high number of passenger trips in a twenty-four period. Twenty per cent of one-vehicle households make more than ten trips per day, but those households account for 50 per cent of the trips of all single-vehicle households. By contrast, 40 per cent of the two-vehicle households make more than ten passenger trips per day, but account for only 65 per cent of all two-vehicle household trips. Obviously, the most active two-vehicle households in trip generation do not make as intensive use of vehicles as do active single-vehicle households. It should be noted, however, that in actual numbers there are about 2.5 times as many one-vehicle households making more than ten trips a day than there are two-vehicle households. It might be speculated that an increase in the number of single-vehicle households extremely active in trip production might lead in the future to a rate of traffic generation equal to that produced by an increase in the number of two-vehicle households.

(6) Two factor analyses were made of social characteristics of households averaged by zones as associated with indices of traffic such as number, time, and purpose of trips. One analysis represented the households of drivers only, the other of households of drivers with passengers. In both cases the matrix of inter-correlations of some thirty items were reduced to a set of four factors which appeared to satisfy statistical criteria appropriate for the data. The first factors of each set appeared identical: A complex of traits showing that the volume of trip generation by zone was positively associated with the socio-economic-occupational level of zone. In both cases, this first factor accounts for almost one-fourth of the matrix variance and shows most clearly association of household characteristics and traffic. This result appears to demonstrate that the higher the economic-occupational level of the population of an area the higher its rate of trip production.

(7) Neither of the other factors in the two sets showed similar correspondence,

nor did they individually account for as high an amount of variance. In the driver-only trip analysis a second factor emerges showing a relation between older drivers and trip purpose for work or business. The third factor in this set linked time of trip to home and distance of residence from CBD. The remaining factor did not involve indices of traffic, but rather the size of household and socio-economic level. The set of factors for household characteristics of drivers with passengers included a second factor involving long-time residents leaving for home earlier on trips from business or work. A third factor shows linkage between younger drivers, inexpensive makes of vehicle, and larger sized household. The fourth factor in this set suggests that a larger proportion of members of lower socio-economic households make trips as passengers. These two sets of factors suggest that trips with passengers are generated by different aspects of households than trips with drivers only, although in both cases the major element involved in the number of trips is occupational-economic level.

In both sets of analyses the leading factors accounted for only 55 per cent of the variance in the matrix of correlation of items. At the same time, however, almost all of the eight leading factors involved aspects of traffic such as number, time of purpose of trips, proportion of household-making trips, etc. The fact that barely a majority of the variance could be accounted for by the complex of traits linked to indices of traffic suggests that either traffic is a product of a multiplicity of influences or else that the present inventory of items of households does not adequately represent household characteristics associated with traffic production.

The leading factor linking amount of trip generation with socio-economic-occupational level provides the basis for a multiple correlation formula which expresses the number of trips as the dependent variable and the household indices of economic level as the independent variables. These traits include zone averages for occupational level, value of residential structure, value of make of car, and distance from CBD, although the latter was also introduced as a control variable since it had been used in other studies. The coefficient of multiple correlation $R_{1.234}$ of these traits as the independent variables with median number of vehicular trips per zone was of the order of .80. This correlation was as high as any discovered using only zone averages of household characteristics as independent variables in correlations with amount of trip generation as the dependent variable. One point of interest with this particular equation is that distance from CBD in itself contributes very little in the prediction of the number of trips generated by zone. The main reason for the limited influence of the distance from CBD is that as a variable it is apparently also correlated with measures of economic-occupational level which are most directly related to traffic production.

(8) Other variables can predict the average generation per zone as well, if not better, than those used in the equation noted above. Such variables had already been presented in earlier chapters as average numbers of vehicles and persons per household. These two zonal averages, treated as the independent variables in a multiple correlation equation in which median number of vehicular trips per zone was the dependent gave an $R_{1.23}$ also of the order of .80. While such characteristics may serve as efficient predictors of traffic production, they are not in themselves as instructive of qualities of households which are influences leading to production of more trips. Socio-economic level as a trait is, presumably, a better motivational explanation of why a household generates traffic than is simply the number of vehicles per household. The difference in the potential for trip generation of the vehicle in the one- and two-vehicle household indicates one explanation of why the number of vehicles per se is not an explanatory item.

(9) The proportion of two-vehicle households in survey zones appear to be a complicating dimension to the attempt to predict or explain traffic generation by zone. The present study found a low coefficient of correlation between the median number of trips by two-vehicle households and the median number of trips for all zone households. This low quantitative relation, however, appeared to be produced by a small number of quite deviant cases, i.e., heterogeneous and somewhat atypical zones in which two-vehicle households differed considerably in trip production from the pattern of other households, and homogeneous zones in which the rate of trip production is closely correlated with the over-all zone rate.

(10) An increase in the socio-economic-occupational level of households appears to be the major influence for increasing the rate of trip generation by zone. Other aspects of trips such as the time of trip, trip-purpose, or the proportion of households making trips appear to be linked, although less obviously than the number of trips, to other characteristics of households such as age of the driver, length of residence in the community, number of persons in household, etc.

(11) All of the above findings, especially the difference in pattern of

traffic generation of one- and two-vehicle households, suggest that the household itself is the basic unit of production of trips, and that production of trips varies by zone measures of households. It is clear from the findings reported in this chapter that any particular items or factors used to define household characteristics provide for somewhat limited prediction of measures of traffic in a community such as that analyzed in the present study.

V. THE RELATION OF SELECTED PHYSICAL MEASURES INCLUDING DENSITY AND DISTANCE TO HOUSEHOLD TRAFFIC GENERATION

The findings of the previous chapter indicated that certain traits of households such as their socio-economic level were closely associated with the rate of trip generation by households. These findings can be expressed as the rate of trip production per household by survey zone. In the present chapter consideration will be given to findings from the Champaign-Urbana survey involving the physical aspects of zones, i.e., density of households and the distance of the zone from other zones, as these aspects appear involved in traffic generation by households.

Physical dimensions of the community have an integral relation to the generation of trips especially when geographical areas such as survey zones are viewed as specific sources of traffic production. For example, if the average rate of trip generation by households in a community is known, then the predicted volume of trips for a geographical area or zone is dependent on the number of households in the area. This number can be stated or standardized as a density per some physical measure such as square feet or acres. Similar physical considerations appear to be involved in the distances between survey zones, since the greater the distance between areas, the fewer the trips made between them. The understanding of the process of traffic generation would be greatly furthered if statistics or parameters of physical aspects of communities relative to trip-making were established. For example, if the rate of trip production per acre of single-households in the middle-economic-occupational range were known, it could be applied to various problems of community traffic engineering or prediction. The present chapter explores questions of establishing such parameters or statistics from the findings of the Champaign-Urbana survey.

A. DENSITIES AS MEASURES RELATED TO TRAFFIC GENERATION

Various measures of density have been applied to land areas of communities as correlates of trip production. These indices have included the number of vehicles and/or households per acre or square mile.

In the present study the density measure used was the average number of trips per developed acre of survey zone for the following items: passenger trips, vehicular trips, vehicles, and households. The measures of association of these items with each other and with the characteristic of households were computed in the form of coefficients of correlation. A number of computations were made for these items such as densities per the number of survey zone acres legally zoned for single- and multi-family residences. Densities by developed acres, however, were most effective for prediction of trip generation by survey zones.

The association between trips, vehicles, and households when stated in terms of densities or the ratio of these items to acres is suggested by Table 17. This table shows the zero-order correlation coefficients between the actual numbers of vehicular trips, the number of vehicles, and the number of households for the forty-one survey zones and the coefficients when each of these items is computed per the number of acres in each zone.

The high correlations found in Table 17 agree with the findings of the Detroit[10] and Chicago[11] studies. There is, however, one noticeable implication in Table 17 shown in the reduction of the size of all three coefficients of correlation when computed in terms of densities per acre. It would appear that the internal relations between the complex of traits, numbers of vehicular trips, households, and vehicles, is reduced when these traits are converted to ratios representing the density of these traits per acre. Two possibilities offer themselves as interpretations of this general reduction of correlation coefficients. The first possibility is that the general reduction in correlation is a consequence of a statistical artifact produced by correlating ratios of traits in which the distribution of the characteristic used as the base of the ratio, in this case the number of acres in each survey zone, is not normally distributed. The introduction of a base not normally distributed may produce a set of ratios which are not normally distributed so that the variance between the measures used in the coefficient of correlation does not have the property of "homoscedasticity" expected in such a coefficient.

One way of testing this possibility is to examine the distribution of the range by size of survey zones, to ascertain the degree to which it approaches a normal distribution. The basis for such an examination is found in Table 18.

The size of survey zones in this table represents "developed acres," which means that a street plan and utilities had been officially approved for the area.

There is obviously a great range in size of survey zones from slightly more than twenty-five acres to over three hundred acres. This disparity in size was required by the desirability of maintaining homogeneity in zones. The distribution of items in Table 18 is reasonably symmetrical although it shows a kind of central bi-modality. The fact, however, that it is not markedly skewed suggests that it is not the pattern of this distribution as the base of the density ratios for zones which produced the reduction in correlation coefficients between variables measured as densities.

One point, perhaps, should be noted relative to the possibilities of analysis suggested by Table 17. The vehicular trips referred to here are all of those made by vehicles maintained by households located in the zone. These trips are not simply ones made to or from the zone. Therefore, the figures for vehicular trips per acre per survey zone is a measure of the average number of trips per acre of all the trips made by vehicles garaged within the survey zone. This index reduces to a space measure the trip generating capacity of the households located in the zone. The rationale behind the creation of such an index is that if such trip generating capacity could be standardized for categories of community space, the prediction of total traffic production by the community would be facilitated.

A second point relative to analysis by density measures should also be noted, namely that this kind of analysis has been limited in some cases, such as the Detroit study, to residential space as defined by zoning regulations. In the present study the unit of area was the developed acre rather than the residential acre. This decision was made after discovering that the use of developed acres gives a better prediction of actual vehicular trips per acre than residential acres as legally zoned. Of the thirty-three cases of survey zones for which it was possible to make predictions for the number of vehicular trips on the basis of both residential and developed acres, in nineteen cases developed acres offered the most accurate prediction, in five cases residential acres offered the most accurate prediction, and in nine cases the predictions were approximately equal in accuracy. The explanation for the more satisfactory prediction through the category of developed acres rests, in this case, on the fact that classifications such as "residential," "commercial," "public space," etc., are zoning categories which permit a certain land use but do not necessarily deny residential use of the same area. For example, land in the commercial category could also contain households as it did in many cases in or near

SUPPORTING DATA

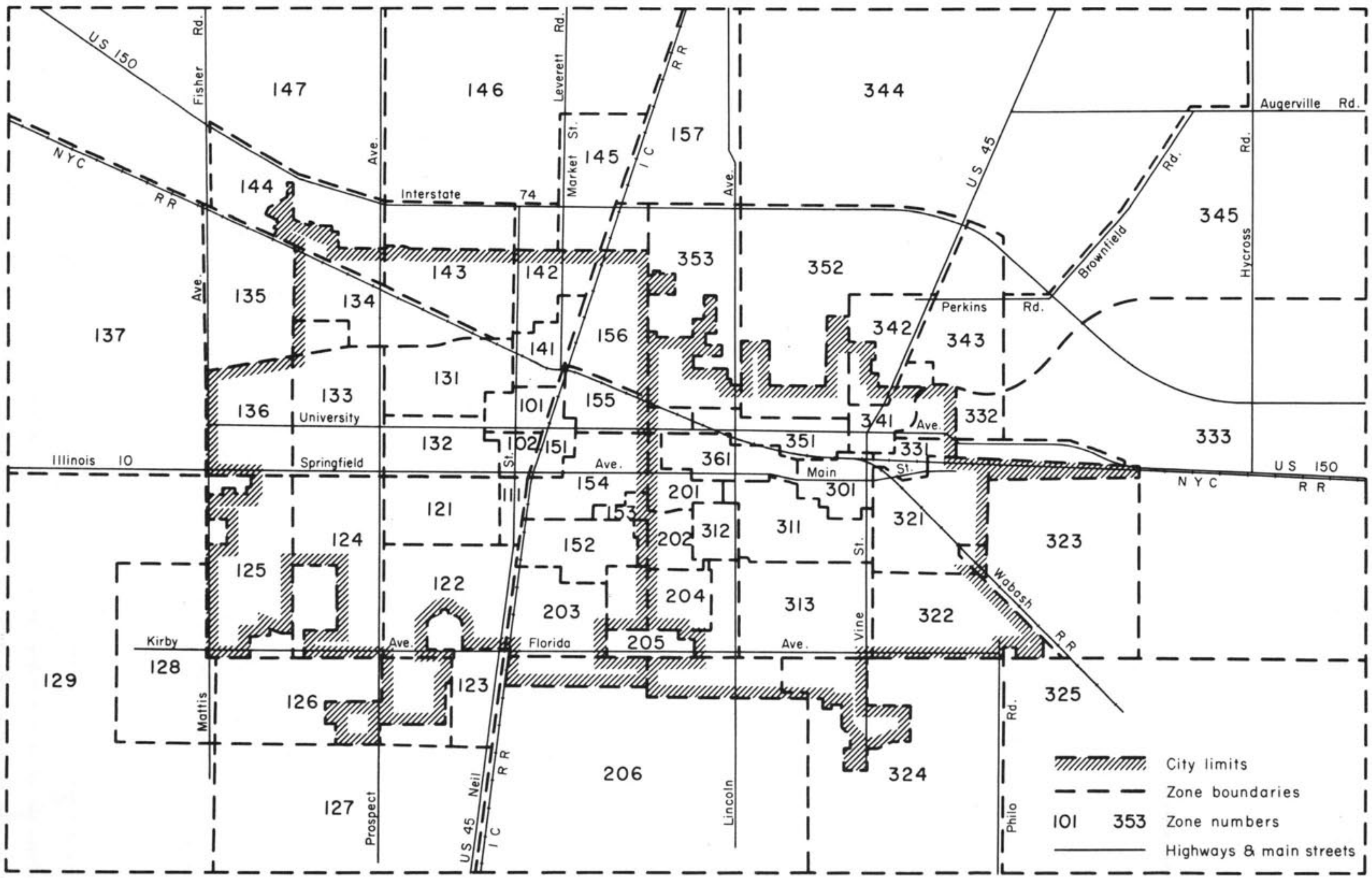

FIGURE 1. CHAMPAIGN-URBANA ZONES

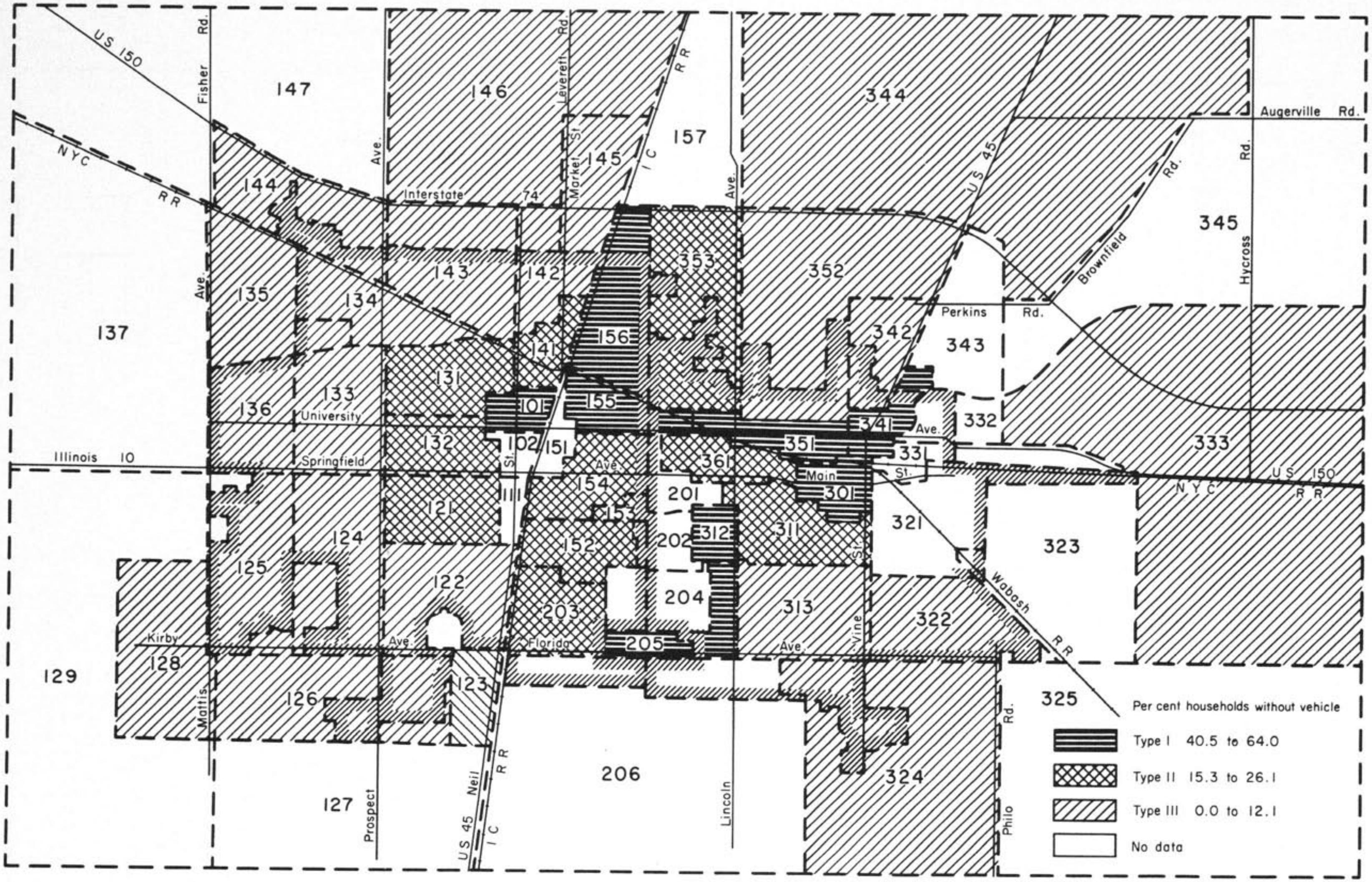

FIGURE 2. TYPES OF ECOLOGICAL PATTERNS

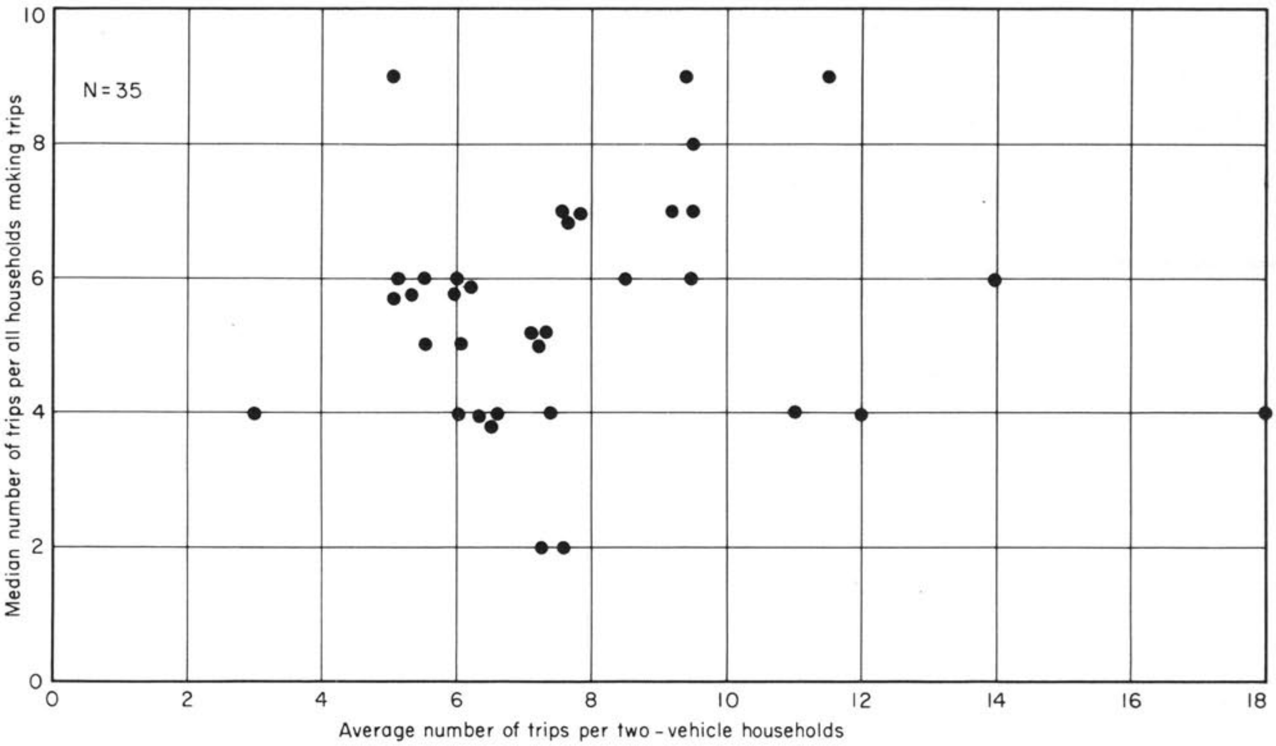

FIGURE 3. RELATION BY SURVEY ZONE BETWEEN MEDIAN NUMBER OF TRIPS FOR ALL HOUSEHOLDS MAKING TRIPS AND TWO-VEHICLE HOUSEHOLD TRIPS

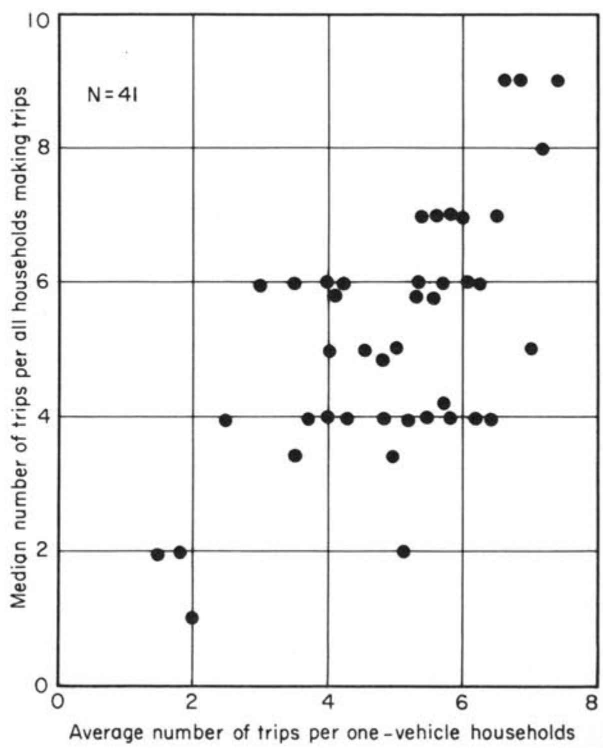

FIGURE 4. RELATION BY SURVEY ZONE BETWEEN MEDIAN NUMBER OF TRIPS FOR ALL HOUSEHOLDS MAKING TRIPS AND ONE-VEHICLE HOUSEHOLD TRIPS

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Table 1

ZERO-ORDER INTER-CORRELATIONS OF NUMBER OF TRIPS PER HOUSEHOLD (ITEM 7) WITH OTHER HOUSEHOLD CHARACTERISTICS -- DATA UNGROUPED BY ZONES

Non-Student Households

	1	2	3	4	5	6	7	8	9
1	-	-.255	.143	.130	.043	-.218	.126	.133	-.064
2			-.238	.015	-.016	.034	-.185	-.131	.111
3				.283	.332	-.024	.427	.482	-.060
4					.879	-.142	.388	.523	.495
5						-.003	.437	.599	.543
6							-.071	-.073	.074
7								.762	-.228
8									-.258
9									-

Student Households

	1	2	3	4	5	6	7	8	9
1	-	.285	-.167	.015	.013	.014	-.111	-.079	.075
2			-.202	.010	.005	-.066	-.183	-.136	.153
3				.066	.060	.107	.490	.389	-.381
4					.954	.036	.013	.058	.158
5						.030	-.007	.055	.158
6							.109	.115	-.132
7								.660	-.659
8									-.919
9									-

Code For Items

(1) Distance from CBD of zone of household
(2) Socio-economic status of zone of household (range: 1 high, 7 low)
(3) Number of cars owned in household
(4) Number of persons in household
(5) Number of persons over age of five in household
(6) Length of residence of household in dwelling place
(7) Number of trips made by members of household during preceding day
(8) Number of persons in household making trips
(9) Number of persons in household making no trips

Table 2

SCALE OF ZONE HOMOGENEITY FOR THIRTY-FOUR SURVEY ZONES

(Scale values based on agreement between measures of occupation, make of car, and value of structure)

Degree of Homogeneity (0-High; 4-Low)	Number of Zones
0	3
1	16
2	5
3	8
4	2
	TOTAL 34

Table 3

SUMMARY OF ANALYSIS OF VARIANCE ABOUT REGRESSION COEFFICIENT BETWEEN NUMBER OF VEHICLES PER ZONE AND NUMBER OF TRIPS PER ZONE - FORTY-ONE SURVEY ZONES

Variance Source	Sum of Squares	Degrees of Freedom	Variance Estimate	F-Ratio
Between zones	4,600.286	40	115.07	3.118*
Within zones	60,404.036	1,639	36.854	
TOTAL	65,004.322	1,679		

*Significant at better than .01 level

Table 4

ZERO-ORDER CORRELATION BY ZONE AVERAGE OF SOCIAL CHARACTERISTICS WITH TRAFFIC GENERATION (ITEM 15) -- NON-STUDENT SAMPLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	-.220	.515	.567	-.416	.479	.216	.528	-.209	-.266	-.158	-.381	-.003	.265	.461
2		-.571	-.462	.206	-.045	-.093	-.344	.470	-.300	-.151	.239	-.320	-.479	-.495
3			.937	.040	.619	.616	.861	-.284	.010	-.424	-.236	.161	.726	.797
4				-.025	.631	.558	.813	-.179	-.100	-.528	-.216	.264	.667	.780
5					.164	.469	.164	.277	.056	-.258	.383	-.349	.164	000
6						.872	.789	.135	-.158	-.544	-.221	-.156	.217	.604
7							.804	.078	.074	-.562	-.065	-.259	.402	.596
8								-.223	.054	-.543	-.314	-.079	.754	.847
9									-.294	-.085	.305	-.124	-.430	-.262
10										.117	-.021	.071	.304	.187
11											-.079	-.285	-.412	-.453
12												.026	-.183	-.321
13													.128	.246
14														.733
15														

Code For Items

(1) Distance from the CBD
(2) Socio-economic type
(3) Average number of cars per household
(4) Per cent of households with cars
(5) Average length of residence
(6) Average number of persons per household
(7) Average number of persons per household over five years of age
(8) Average number of persons making trips
(9) Median year of cars
(10) Average make of cars
(11) Average value of structure
(12) Coefficient of variability
(13) Average number of trips per person making trips
(14) Per cent of potential trip-makers making trips
(15) Median number of trips

Table 5

COMPARISON OF COEFFICIENTS OF CORRELATIONS OF NUMBER OF PASSENGER TRIPS WITH OTHER INDICES OBTAINED BY TWO SETS OF DATA: HOUSEHOLDS AND ZONE AVERAGES

Zero-Order Correlation

Number of Trips with Items Indicated

(1) Item	(2) By Household	(3) By Zone Average	(4) Increase in Amount of Variance ((3)-(2))
1. Distance from CBD of zone of household	.126	.461	.197
2. Socio-economic status of zone of household (range: 1 high; 7 low)	-.185	-.495	.211
3. Number of vehicles in household	.427	.797	.453
4. Number of persons in household	.388	.604	.214
5. Number of persons over age five in household	.437	.596	.164
6. Length of residence of household in dwelling	-.071	000	---
7. Number of persons in household making trips	.762	.847	.133

Table 6

COMPARISON OF RANKINGS BY SIZE OF THE COEFFICIENTS OF CORRELATION REPORTED IN TABLE 5

Item	Ranking Correlated by Household	Ranking Correlated by Zone Average
Number of vehicle in household	3	2
Number of persons in household	4	3
Socio-economic status of zone	5	5
Distance of zone from CBD	6	6
Number of persons over age five in household	2	4
Number of persons in household making trips	1	1
Length of residence of household	7	7

Table 7

OF THREE RINGS OF SURVEY ZONES IN CHAMPAIGN-URBANA --

HOUSEHOLD CHARACTERISTICS AND TRAFFIC GENERATION

GROUPED BY DISTANCE FROM THE CBD

(1) Ring Number	(2) Number of Zones Included	(3) Per Cent of Households in Total Sample	(4) Per Cent of Trips in Total Sample	(5) Per Cent of Ring Households Owning Vehicles	(6) Average Distance of Zones from CBD (1/10 mi.)	(7) Average Number of Trips per Household	(8) Average Number of Trips per Vehicle Household
I	7	10.7	6.9	54	64	3.62	6.75
II	12	30.5	25.5	77	87	4.70	6.07
III	22	58.8	67.7	93	164	6.47	6.98
TOTAL	41	100.0	100.0				

Code for Items

(1) Ring designation
(2) Number of survey zones in ring
(3) Percentage of all households in ring
(4) Percentage of all trips made by households
(5) Percentage of ring households owning vehicles
(6) Average distance of zones in ring from CBD
(7) Average number of trips per household
(8) Average number of trips per vehicle-owning household

Table 8

AVERAGE NUMBER OF VEHICULAR TRIPS PER HOUSEHOLD AND AVERAGE NUMBER

OF TRIPS PER VEHICLE ACCORDING TO NUMBER

OF VEHICLES PER HOUSEHOLD

Vehicular Trips

Number of Vehicles per Household	Number of Households	Driver Only	Driver and Passenger(s)	Total	Average Number of Vehicles per Household	Average Number of Trips per Vehicle
0	321	0	0	0	0	0
1	1,365	5,134	2,508	7,642	5.6	5.6
2	301	1,664	718	2,382	7.6	3.8
TOTAL	1,987	6,798	3,226	10,024		

Table 9

PERCENTAGE OF NUMBER OF PASSENGER TRIPS MADE BY PERCENTAGE OF HOUSEHOLDS CONTAINING ONE AND TWO VEHICLES -- HOUSEHOLD SURVEY SAMPLE

	One-Vehicle Households		Two-Vehicle Households	
(1) Number of Trips	(2) Per Cent of All Household Trips in This Category	(3) Per Cent of Households Making This Number of Trips	(4) Per Cent of All Household Trips in This Category	(5) Per Cent of Households Making This Number of Trips
0	0	5.7	-	-
1- 2	4.0	15.1	.7	3.7
3- 4	10.3	19.9	4.1	11.4
5- 6	12.3	16.1	10.6	19.4
7- 8	12.8	12.2	9.9	13.7
9-10	12.2	9.4	10.3	11.4
11-12	9.9	6.2	9.5	8.7
13-14	7.7	4.2	11.4	9.0
15-16	7.4	3.5	4.4	3.0
17-18	5.2	2.2	12.1	7.4
19-20	4.7	1.8	7.3	4.0
21-22	3.0	1.0	6.7	3.3
23-24	2.1	.7	3.0	1.3
25-26	2.7	.8	1.6	.7
27-28	1.6	.4	2.6	1.0
29-30	.9	.2	2.8	1.0
31-40	3.2	.6	3.0	1.0
TOTAL	100.0	100.0	100.0	100.0
n =	10,254	1,394	3,189	299
Average Number of Passenger Trips per Household		7.36		10.66

Class Interval in Which Household Median, Mode, and Mean Fall

Mode	3-4	5- 6
Median	5-6	9-10
Mean (average)	7-8	10-11

Table 10

LIST OF TRAITS OF HOUSEHOLDS IN SURVEY ZONES AND MEASURES OF TRAFFIC GENERATION

A. Traits of Households by Survey Zones (Independent Variables)

1. Scale value of occupations
2. Median sex-race
3. Median purpose of trip from home
4. Median purpose of trip to home
5. Time of trip -- morning median from home
6. Time of trip -- afternoon median from home
7. Time of trip -- morning median to home
8. Time of trip -- afternoon median to home
9. Median number of persons in vehicle for trip
10. Median age of driver of vehicle
11. Distance of zone from CBD
12. Socio-economic level of zone
13. Average number of vehicles per household
14. Average length of residence of household
15. Average number of persons per household
16. Average number of persons per household who made trips
17. Median age of household vehicles in years
18. Average type of vehicle (low, medium, and high priced)
19. Average value of residential structures
20. Per cent of potential trip-makers who make trips
21. Average number of trips made by persons making trips
22. Median number of passenger trips
23. Number of vehicular trips per developed acre
24. Number of developed acres per household
25. Homogeneity of zone -- in terms of type and age of vehicle
26. Homogeneity of zone -- in terms of value and residential structure

B. Measures of Traffic Generation (Dependent Variables)

1. Average number of vehicular trips per household
2. Average number of vehicular trips per vehicle, one-vehicle households
3. Average number of vehicular trips per vehicle, two-vehicle households

Table 11

MEANS AND STANDARD DEVIATIONS OF VARIABLES ASSOCIATED WITH VEHICULAR TRAFFIC FOR TRIPS WITH ONE PERSON AND MORE THAN ONE PERSON IN VEHICLE

		More Than One in Car		Driver Only	
		Arith. Means	Standard Deviation	Arith. Means	Standard Deviation
1	Scale value of occupations	+3.024	+1.752	+3.000	+1.859
2	Median sex-race	+1.238	+0.479	+1.227	+0.470
3	Purpose from home	+4.667	+1.847	+1.546	+1.033
4	Purpose to home	+3.905	+1.525	+1.364	+0.882
5	Time of trip -- morning median from home	+8.000	+0.870	+7.680	+0.700
6	Time of trip -- afternoon median from home	+17.240	+1.270	+17.000	+1.280
7	Time of trip -- morning median to home	+10.520	+1.010	+9.890	+1.050
8	Time of trip -- afternoon median to home	+17.380	+1.200	+16.930	+0.690
9	Median age of auto-drivers	+36.790	+7.060	+39.320	+7.510
10	Median number of persons in vehicle	+2.024	+0.153	+1.000	+0.000
11	Distance from CBD	+12.980	+8.320	+12.710	+8.270
12	Socio-economic type	+4.405	+1.070	+4.432	+1.053
13	Average number of cars per household	+0.972	+0.247	+0.965	+0.244
14	Average length of residence	+3.544	+0.674	+3.549	+0.662
15	Average number of persons per household	+2.992	+0.559	+2.971	+0.554
16	Average number of persons making trips (passenger trips included)	+1.651	+0.455	+1.643	+0.447
17	Median year of car models	+5.380	+1.420	+5.360	+1.400
18	Average make of cars	+1.541	+0.139	+1.545	+0.137
19	Average value of structure	+14.650	+8.980	+14.480	+8.810
20	Per cent of potential trip-makers making trips (passenger trips included)	+54.740	+10.220	+54.840	+10.010
21	Average number of trips per person making trips (passenger trips included)	+3.228	+0.362	+3.236	+0.356
22	Median number of trips (passenger trips included)	+5.214	+1.931	+5.136	+1.923
23	Average number of trips per car (vehicular traffic)	+4.485	+1.065	+4.478	+1.042
24	Number of vehicular trips per developed acre	+1.411	+0.791	+1.361	+0.806
25	Number of developed acres per household	+4.350	+4.500	+0.441	+0.442
26	Average number of trips per car, two-car households	+3.252	+1.681	+3.258	+1.643
27	Average number of trips per car, one-car households	+4.921	+1.293	+4.919	+1.263
28	Homogeneity factor -- in terms of car type and age	+3.476	+1.384	+3.432	+1.372
29	Homogeneity factor -- in terms of real estate values	+2.810	+1.096	+2.818	+1.072

Table 12

SELECTED FACTOR LOADINGS -- FIRST FIVE FACTORS

Rotated Orthogonal Factor Loadings on Twenty-eight Variables Associated with Vehicular Trips Containing Only Driver in the Car -- Centroid Solution with Fixed Communalities

(Values approximately .5 or higher)

Factor	A	B	C	D	E
Variable 1	-.612				
2					
3		-.658			
4		-.722			
5					-.405
6					
7					
8			-.509		
9		+.633			
10			+.578		
11	-.710				
12	+.749				
13		+.685			
14				+.534	
15	+.681				
16					
17					-.411
18				-.494	
19	+.649				
20					
21	+.784				
22	+.655				
23	+.588				
24					
25	+.609				
26	+.684				
27					+.405
28					

Variable 1 Scale value of occupations
2 Median sex-race
3 Purpose from home
4 Purpose to home
5 Time of trip -- morning median from home
6 Time of trip -- afternoon median from home
7 Time of trip -- morning median to home
8 Time of trip -- afternoon median to home
9 Median age of auto-drivers
10 Distance from CBD
11 Socio-economic type
12 Average number of cars per household
13 Average length of residence
14 Average number of persons per household
15 Average number of persons making trips (passenger trips included)
16 Median year of car models

Table 12 (continued)

Variable	17	Average make of cars
	18	Average value of structure
	19	Percentage of potential trip-makers making trips (includes passenger trips)
	20	Average number of trips per person making trips (passenger trips included)
	21	Median number of trips (passenger trips included)
	22	Average number of trips per car (vehicular traffic)
	23	Number of vehicular trips per developed acre
	24	Number of developed acres per household
	25	Average number of trips per car, two-car households
	26	Average number of trips per car, one-car households
	27	Homogeneity factor -- in terms of car type and age
	28	Homogeneity factor -- in terms of real estate values

Percentage of Variance Attributable to Each of Five Factors

Factor	Per Cent of Variance
A	25.1
B	10.8
C	10.4
D	7.9
E	5.9

Table 13

SELECTED FACTOR LOADINGS -- FIRST FIVE FACTORS

Rotated Orthogonal Factor Loadings on Twenty-nine Variables Associated with Vehicular Trips Containing Driver and One or More Passengers in Car -- Centroid Solution with Fixed Communalities

(Values approximately .5 or higher)

Factor	A	B	C	D	E
Variable 1	-.583				
2					
3					+.491
4		-.589			
5		-.509			
6					
7					
8	+.531				
9			-.567		
10					
11					
12	-.628				
13	+.789				
14		+.690			
15			+.536		
16	+.764				
17					
18			-.540		
19					
20	+.723				
21				-.538	
22	+.852				
23	+.735				
24	+.621				
25					
26	+.610				
27	+.770				
28					
29					

Variable 1 Scale value of occupations
2 Median sex-race
3 Purpose from home
4 Purpose to home
5 Time of trip -- morning median from home
6 Time of trip -- afternoon median from home
7 Time of trip -- morning median to home
8 Time of trip -- afternoon median to home
9 Median age of auto-drivers
10 Median number of persons in car
11 Distance from CBD
12 Socio-economic type
13 Average number of cars per household
14 Average length of residence
15 Average number of persons per household
16 Average number of persons making trips (passenger trips included)

Table 13 (continued)

Variable 17	Median year of car models
18	Average make of cars
19	Average value of structure
20	Percentage of potential trip-makers making trips (passenger trips included)
21	Average number of trips per person making trips (passenger trips included)
22	Median number of trips (passenger trips included)
23	Average number of trips per car (vehicular traffic)
24	Number of vehicular trips per developed acre
25	Number of developed acres per household
26	Average number of trips per car, two-car households
27	Average number of trips per car, one-car households
28	Homogeneity factor -- in terms of car type and age
29	Homogeneity factor -- in terms of real estate values

Percentage of Variance Attributable to Each of Five Factors

Factor	Per Cent of Variance
A	21.9
B	14.6
C	9.0
D	8.8
E	7.8

Table 14

COEFFICIENT OF MULTIPLE CORRELATION BETWEEN AGENCY NUMBER OF VEHICULAR TRIPS BY ZONE AND SELECTED SOCIAL CHARACTERISTICS OF HOUSEHOLDS AVERAGED BY ZONE

(Trips with Driver Only)

$$R_{1.2345} = .809$$

Where:		Beta Coefficient
R_1	= average number of trips per zone	
R_2	= average value of occupations per zone	-.451
R_3	= average value of structure per zone	-.467
R_4	= average per zone of the make by price of cars	.435
R_5	= distance of the zone from the CBD	.165

Table 15

COEFFICIENT OF MULTIPLE CORRELATION OF MEDIAN NUMBER OF VEHICULAR TRIPS PER ZONE WITH AVERAGES OF NUMBER OF VEHICLES AND PERSONS PER HOUSEHOLD

$$R_{1.23} = .809$$

Where:		Beta Coefficient
R_1	= median number of trips per household per zone	
R_2	= average number of vehicles per household per zone	.686
R_3	= average number of persons per household per zone	.179

Table 16

COEFFICIENTS OF CORRELATION BETWEEN MEDIAN NUMBER OF PASSENGER TRIPS PER ZONE AND AVERAGE NUMBER OF TRIPS BY ONE- AND TWO-VEHICLE HOUSEHOLDS

	Correlation Coefficient
Average Number of Trips per Two-Vehicle Household	.249
Average Number of Trips per One-Vehicle Household	.802

Table 17

COMPARISON OF ZERO-ORDER COEFFICIENTS OF CORRELATION BETWEEN VEHICULAR TRIPS AND VEHICLES AND HOUSEHOLDS COMPUTED BY TOTAL NUMBERS PER SURVEY ZONE AND BY NUMBER PER SURVEY ZONE ACRE -- FORTY-ONE SURVEY ZONES

Coefficients of Correlation "r"

	Vehicles per Survey Zone	Households per Survey Zone
Vehicles per survey zone		.946
Vehicular trips per survey zone	.981	.924
For Number per Acre by Survey Zone		
	Vehicles per Acre by Survey Zone	Households per Acre by Survey Zone
Vehicles per acre per survey zone		.758
Vehicular trips per acre per survey zone	.939	.836

Table 18

SIZE OF FORTY-ONE SURVEY ZONES IN DEVELOPED ACRES

Number of Acres	Number of Zones	Number of Acres	Number of Zones
25- 49	2	200-224	3
50- 74	4	225-249	2
75- 99	4	250-274	-
100-124	7	275-299	2
125-149	3	300-324	2
150-174	4	325-349	-
175-199	7	350-374	1

Table 19

VEHICULAR TRIPS PER DEVELOPED ACRE ZONE BASED ON HOUSEHOLD

SAMPLE -- FORTY-ONE SURVEY ZONES

Trips Per Acre	Number of Zones	Trips Per Acre	Number of Zones
0 - .24	3	1.75-1.99	4
.25- .49	2	2.00-2.24	2
.50- .74	5	2.25-2.49	2
.75- .99	2	2.50-2.74	1
1.00-1.24	4	2.75-2.99	3
1.25-1.49	8	3.00-3.24	1
1.50-1.74	4		

Ave. = 1.49
S.D. = .77

Table 20

PERCENTAGE BY ZONE OF POTENTIAL TRIP-MAKERS REPORTED

MAKING TRIPS -- FORTY-ONE SURVEY ZONES

Per Cent of Trip-Makers Making Trips		Number of Zones
Less than 34		1
35-39		2
40-44		2
45-49		6
50-54		5
55-59		14
60-64		4
65-69		5
70-74		2
	TOTAL	41
	Average	55.5

Table 21

TRAITS RELATED TO TRAFFIC GENERATION OF LOW, AVERAGE, AND HIGH TYPES

OF ZONES DEFINED BY PER CENT OF TRIP-MAKERS POTENTIAL MAKING TRIPS

(Per Cents Are of the Totals for All Zones)

Type	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Low	14.7	12.6	9.7	9.9	5.0	.87	3.9	4.5
Medium	26.6	26.2	26.4	27.2	27.3	2.11	2.5	6.1
High	17.3	19.8	23.0	19.9	32.6	1.35	1.4	7.1

(1) Per cent of households in total household sample
(2) Per cent of vehicles owned in sample
(3) Per cent of all vehicular trips in sample
(4) Per cent of vehicular trips made by families owning one car
(5) Per cent of vehicular trips made by families owning two cars
(6) Vehicular trips per developed acre
(7) Occupational level (low values show higher occupational value)
(8) Average number of vehicular trips per household

Table 22

VOLUME OF INTERCHANGE BETWEEN ZONES, TRIPS TO CBD AND INTRAZONE TRIPS -- FORTY-ONE SURVEY ZONES

Zone Number	Number of Interchange Trips	Trips to CBD (Zones 101 & 301)	Intrazone Trips
101	23,217	508	1,428
121	5,332	583	376
122	6,227	843	625
123	1,053	44	7
124	6,152	806	819
125	5,087	646	978
126	2,394	281	247
128	2,274	175	347
131	3,418	509	166
132	9,750	822	561
133	6,130	768	551
134	5,150	591	595
135	976	61	19
136	5,212	800	785
141	4,126	369	106
142	2,148	247	205
143	3,506	412	162
144	3,101	398	265
145	1,878	161	80
146	682	75	19
152	6,709	765	641
154	6,239	498	355
155	5,294	425	310
156	2,830	386	533
203	4,464	536	322
205	3,296	214	180
301	14,054	508	792
311	7,817	1,216	783
312	4,130	453	143
313	6,477	860	1,006
321	5,257	1,080	708
322	4,970	804	1,049
324	2,917	388	558
333	349	55	10
341	2,677	201	60
342	1,851	318	176
344	725	83	0
351	4,223	395	250
352	2,352	293	30
353	2,514	304	275
361	4,045	508	258
TOTAL	191,003	19,369	16,780

Table 23

COMPARISON OF RANKINGS BY ZONES FOR TOTAL NUMBER OF PASSENGER TRIPS AND FOR TOTAL NUMBER OF INTERCHANGE TRIPS -- FORTY-ONE SURVEY ZONES

(1) Zone Number	(2) Ranking -- Interchange Trips	(3) Ranking -- Passenger Trips	Difference in Ranks (3) - (2)
101	1	41	40
301	2	29	27
132	3	11	8
311	4	2	-2
152	5	1	-4
313	6	3	-3
154	7	15	-8
122	8	5	-3
124	9	9	0
133	10	8	-2
121	11	13	2
155	12	30	18
321	13	4	-9
136	14	10	-4
134	15	14	-1
125	16	12	-4
322	17	7	-10
203	18	6	-12
351	19	33	14
312	20	17	-3
141	21	38	17
361	22	18	-4
143	23	21	-2
131	24	19	-5
205	25	23	-2
144	26	20	-6
324	27	16	-11
156	28	22	-6
341	29	40	11
353	30	25	-5
126	31	27	-4
352	32	32	0
128	33	24	-9
142	34	26	-8
145	35	31	-4
342	36	28	-8
123	37	34	-3
135	38	35	-3
344	39	39	0
146	40	36	-4
333	41	37	-4

Table 24

NUMBER AND DISTANCE OF TRIPS REPORTED FOR AVERAGE SPRING WEEKDAY INTERCHANGE BETWEEN INTERNAL ZONES

(From Internal Survey)

Distance ($\frac{1}{4}$ Miles)	Number of Trips	Distance ($\frac{1}{4}$ Miles)	Number of Trips	Distance ($\frac{1}{4}$ Miles)	Number of Trips
1	4,347	9	6,125	17	414
2	19,872	10	3,996	18	150
3	20,166	11	3,234	19	137
4	19,965	12	2,222	20	50
5	14,303	13	1,953	21	40
6	11,515	14	1,235	22	44
7	12,505	15	1,022	23	14
8	6,051	16	569	24	32
				TOTAL	129,964

Table 25

RATIO OF THE ACTUAL NUMBER OF TRIPS OF A GIVEN LENGTH TO THE ACTUAL NUMBER OF DISTANCES OF THE SAME LENGTH BETWEEN ZONES EXCHANGING TRIPS

(1) Distance in $\frac{1}{2}$ Miles	(2) Number of Trips	(3) Total Number of Distances Between All Zones	(4) Ratio of Total Number of Zone Distances to Trips (2) ÷ (3)
1	24,220	53	457
2	40,131	142	282
3	25,818	187	138
4	18,556	185	100
5	10,121	193	52
6	5,456	120	45
7	2,188	105	20
8	1,591	67	24
9	564	48	12
10	187	20	9
11	84	19	5
12	46	9	5

Table 26

NUMBER OF PASSENGER TRIPS MADE BY NON-STUDENT HOUSEHOLDS AS REPORTED IN HOUSEHOLD SURVEY

Number of Passenger Trips	Per Cent of Sample Households Making This Number of Trips
0	4.7
1-4	31.7
5-8	29.7
9-12	16.6
13-16	7.5
17-20	5.4
21-24	2.3
25-28	1.3
29 and over	1.0

Number of Households = 1,693

Table 27

MEDIAN NUMBER OF VEHICULAR TRIPS PER SURVEY HOUSEHOLD -- FORTY-ONE SURVEY ZONES

Median Number of Trips	Number of Zones
0	1
1	-
2	3
3	2
4	11
5	5
6	10
7	5
8	1
9	3

Table 28

PER CENT OF ALL SAMPLE NON-STUDENT HOUSEHOLDS CONTAINING TWO VEHICLES AS REPORTED BY ZONE

Per Cent of Households With Two Vehicles	Number of Zones	Per Cent of Households With Two Vehicles	Number of Zones
0	6	21-25	2
1-5	6	26-30	2
6-10	7	31-35	2
11-15	7	36-40	-
16-20	8	41-45	1
		TOTAL	41

Table 29

COMPARISON OF TYPES OF ZONES CLASSIFIED BY PROPORTION OF POTENTIAL TRIP-MAKERS MAKING TRIPS

Type Proportion of Trip-makers Making Trips	1	2	3	4	5	6
Low	28	7.6	180	4.2	208	4.5
Medium	78	7.2	357	5.5	435	6.1
High	87	8.8	239	6.3	326	7.1

1. Number of two-vehicle households
2. Average number of vehicular trips for two-vehicle households
3. Number of one-vehicle households
4. Average of vehicular trips for one-vehicle households
5. Total number of households
6. Average number of vehicular trips for households in type

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the CBD where residential apartments were found over commercial properties. The use of only the residential acres as a basis for predicting total number of trips from a survey zone consistently under-estimated the density per acre of households and vehicles for the whole survey zone. This difficulty was avoided by using the classification of developed acres for each zone which were defined as noted above. These considerations indicate that it is not a statistical artifact derived from the distribution of the data which is ostensibly reducing the correlation.

A second possibility, which may explain the reduction in the correlation coefficients between number of vehicles, number of vehicular trips, and number of households when measured per acre rather than by number per survey zone, is that using acres as a base may introduce the influence of some intervening variable into the correlations. Discovery of such variables and detection of their influence is not always possible in a case such as this. Fortunately, however, information developed concerning the classification of survey zones according to the proportion of potential trip makers reported as making trips suggested why the coefficients of correlation in question were reduced. The gist of this information is contained in Tables 20 and 21 which give the basis of a tri-partite classification of survey zones which distinguishes zones which are high, average, and low in proportion of potential trip-makers making trips. This classification appears to single out patterns of social characteristics of households correlated with traffic. Column 6 of Table 21 shows that survey zones which are average in traffic production by this tripartite classification indicate the highest rate of vehicular trip production per acre. This fact that the highest rate of trip generation per acre is not characteristic of the zones containing the households with the highest rate of trip production is sufficient to explain the reduction in size of coefficient correlations between the items in question. Other implications of this condition will be discussed below.

B. THE RANGE IN NUMBER OF TRIPS PER DEVELOPED ACRE

The utility of the procedure for reducing trip production by households to a density measure relative to the number of acres occupied by households is that the measure produced can be applied to any community. Also, the area serviced by a community roadway network can, through density measures, be defined in terms of varying gradients of trip production which indicate the physical areas which generate the traffic fed into the network. The utilization and interpretation of such a measure calls for estimation of its range and of factors which account for the variation represented by this range. The range of the findings for trips per acre are indicated in Table 19.

The distribution in this table of vehicular trips per developed acre is reasonably symmetrical about the mean of 1.49. In fact, the distribution appears more normal than many of the highly skewed distribution of traits associated with traffic generation.

C. ESTIMATING TOTAL TRAFFIC GENERATION FROM DENSITY PER SURVEY ZONE

The problem of determining the traffic generating potential of each zone one is, however, complicated by the necessity of allowing for sampling error which may be contained in the data found in Table 19. The number of vehicular trips per acre reported in this table are based on the $12\frac{1}{2}$ per cent sample of households in Champaign-Urbana selected for the household interview. The estimation of the actual trips per acre would, therefore, call for multiplying each of the class intervals by eight to compute the vehicular trips for 100 per cent of the households in the survey zone. Unfortunately, however, the number of cases in the distribution is so small that useful confidence limits for the distribution cannot be established for zones at the extreme values.

Therefore, any attempt to estimate the total trip production must use the average for the whole distribution and not the average of each zone.

Following this procedure the number of trips per acre was multiplied by a factor of eight (assuming that a $12\frac{1}{2}$ per cent sample of all households in the community was taken) and these results are obtained: An average of 11.9 trips would be generated for each developed acre. Since there are 6,655 developed 79,194 vehicular trips. An allowance is made for the standard error of estimate of .122 for the distribution in Table 19, then the 5 per cent confidence level for the mean is from 1.25 to 1.73. If the mean were actually the largest value within the confidence limits, some 92,104 vehicular trips could have been produced by the survey zones.

When the estimation of community vehicular trips by this method is compared to the observed vehicular trips, the following picture emerges. Some 167,000 internal vehicular trips were reported.[12] Of these about 72 per cent were attributed in the present study to non-student households; the balance was attributed to student households. Therefore, the present method should have accounted for at least 72 per cent of the observed trips, about 120,700. According to this value the mean number of trips per acre in Table 19 would predict only about 65 per cent of the actual non-student trips and the highest value of the mean reasonably compatible with sampling error would account for 76 per cent of observed trips. The size of this discrepancy between estimated and actual trips is considerable, although it should be noted that as in the survey vehicular trips reported were only 67 per cent of cordon line counts of such trips.

This discrepancy between the number of trips estimated by the trips per acre method and the observed trips cannot be, as in the survey report, resolved through use of an expansion factor because the actual source of the discrepancy is not clear. There appear to be at least three sources of such a discrepancy. First, there is the possibility that the household interview did not actually reach a 12½ per cent sample of the community population because the directories on which the sample was based did not actually contain the listings of all the households in the zones. It is generally accepted that community directories may not always be up to date and may not be fully reliable for the lower socio-economic groupings. Yet, such possible under-estimation in the master sample could not have been very large because the U.S. Census of 1960 for Champaign-Urbana gave a population figure consistent with the estimate for 1958 on which the 12½ per cent sample was based.

A second source of discrepancy may be the role of student trips in the production of the vehicular trip total. Analysis was not made of the per acre trip production by student household, and it may be that the assumption of the proportion which these households contributed to vehicular trips by acres is not correct.

A third source, of course, is respondent error in reporting the number of vehicular trips. The fact of such error is suggested by the need for an expansion factor to bring reported trips and observed trips into agreement. It is possible that all three of these sources of discrepancy were operating with bias in the same direction so as to produce the difference between trips estimated by acres and the actual observed trips. It would appear that study of the data of other surveys is required to determine the utility of the method of estimating the total number of vehicular trips from the average number of trips per acre and to standardize the procedure for such a method if it appears feasible.

D. SOCIAL TRAITS ASSOCIATED WITH TRAFFIC GENERATION BY ZONE DENSITY

One final observation might be drawn from measures of trips per acre. This point concerns a comparison of the observable characteristics of survey zones which generate a relatively low number of vehicular trips and those which produce a high number of such trips. A comparison of the five zones highest to the five zones lowest in number of trips per acre showed the following. Zones high in trips per acre were predominantly single-family residences containing small- to middle-size houses and lots. The zones were in relatively older areas of the community, there were practically no empty lots; public space of facilities such as parks, churches, etc., were relatively few in number and low in ground coverage. These zones tended to be intermediate in community location between the CBD and suburban fringe. These zones were relatively alike in all of these characteristics.

By contrast zones low in trips per acre were far more heterogeneous in characteristics. They included a CBD zone, a zone containing new subdivisions in which there were both large lots and empty lots, a zone which included industrial and railroad property, a zone with much public space including a cemetery, and a zone of varied land uses. These zones could be found in any area of the community. In general, they were residentially undesirable or contained a large number of public or institutionally controlled land areas. If residentially desirable the lots were large and many were empty. These two types of zones would attract households of different socio-economic levels. The real difference in the rate of trip generation, however, seems to be attributable to the differences in the proportion of the zone which is devoted to residential use. At the same time it is significant that none of the zones which were highest in measures on the socio-economic scale were among the highest in trip generation per acre.

E. A "PUSH-PULL" MODEL OF TRAFFIC INTERCHANGE BETWEEN ZONES

The previous discussion has indicated that the method of reducing vehicular traffic to trips per acre requires some refinement if it is to predict actual vehicular trips accurately. At the same time, however, this method as employed here shows that it is not simply the average rate of trip generation per household in a survey zone which accounts for volume of produced trips by the area of the zone, but that the density of households per acre in the zone in combination with the rate of trip generation by these households accounts for traffic volumes produced. The conclusion might then be drawn that households themselves are the primary traffic generators, but that the household density per acre contributes to the volume of traffic from a specified land area. This principle defines what might be called the push to traffic volumes generated by a specified area, or the tendency of the population of a specified area to put their vehicles into movement on the community highway system.

The length of the trips, or the distance traveled, and the direction of the trips may be regarded as the pull of the local traffic system. The nature of this pull and of procedures for measuring and analyzing it has been explored in a number of studies. The Detroit and Chicago transportation studies summarized many of these findings and procedures. From these reports a number of conclusions can be drawn. First, the interchange of trips between two zones is directly proportional to the trip production of each and is indirectly proportional to the distance between them. Second, interchange between zones is practically symmetrical; that is, an equal number of trips go each way in the interchange between two zones. Third, the distribution of trips by length is not a statistically normal distribution, but rather approaches a log normal or exponential curve. This condition seems to result from the fact that as the number of trips in a household increase, the average length of trip decreases. This tendency is also associated with the propensity of the number of purposes to increase as the number of trips increase. For example, certain trips such as those for work which occur as purposes in almost all trip-making households will necessarily be of greater average length than certain other purposes such as social-recreational. Fourth, the CBD and adjacent area constitute the one single area which is the destination of the most trips of any area in the community. At first sight this might seem to contradict the principles of traffic flow stated above, since the CBD appears to attract trips with equal facility from areas which are both near and far away. Actually the CBD and adjacent areas in most communities have only a limited push in trip production per acre or square mile, and the huge volume of interchange traffic between the CBD and the rest of the community has its origin in the pull dimension of the community traffic system.

It would appear then that a predictive model of the pattern of traffic flow in a community could be stated in terms of the tendency toward equilibrium of the push and pull dimensions of the community traffic system. These dimensions as they are expressed in the data normally secured through origin-destination surveys can be defined as follows. Push is the propensity of households to use their vehicle or vehicles to satisfy needs or desires of the members of the household which can be satisfied only outside of the household. These needs or desires are represented by the "trip-purposes" traditionally reported in origin-destination surveys. In almost every case of a purpose it calls for a transaction with someone else, or an activity limited to a prescribed place such as some forms of work or of social-recreational behavior. The trip purpose "to home" is not by definition part of push since it does not involve a desire to be satisfied outside the household. Logically, from the viewpoint of the household member making the trip, the return is actually part of the cost of the trip.

The push-pull concept of community traffic generation sees traffic as an aspect of community consumer economics. Households are the purchasing or consuming units, and they seek to maximize their profits which, as in any economic transaction, are rewards less costs. The reward in this case is the satisfaction of trip purpose, shopping, medical-dental work, etc. One element of the costs is the trip-making itself as it can be converted into expenditure of time, costs of gas and oil, and/or the inconvenience of the conditions of travel. This economic analogy has been applied to trip generation by business enterprises where accounting and bookkeeping make easy the estimate of transportation costs, but it has been rarely utilized with households in the community because of the difficulty of estimating how households maximize their profits from their own trip generation. The findings of the present study suggest a measure which apparently gives some estimation of the profits perceived by household members through making trips. This statistic is the proportion of the potential trip-makers in the household who actually make trips. This measure can also be computed for the whole survey zone.

F. POTENTIAL TRIP-MAKERS AS AN INDEX OF "PUSH" TO TRAFFIC PRODUCTION

The range in the proportion of potential trip-makers making trips when computed by survey zone is both considerable and reasonably symmetrical as is shown by Table 20.

On the basis of the distribution shown in Table 20, it was possible to derive three types of zones, one low in potential trip-making, one average, and one high in this trait. The average zones, eight in number, were those which were either the mean or median values in the distribution; the low zones were one standard deviation below the mean and included seven zones in which 45 per cent or less or potential trip-makers made trips; and the high zones were one standard deviation above the mean and included the seven in which 65 per cent or more of trip-makers made trips. The types, therefore, included 50 per cent of the actual cases located at the extreme and central points of the distribution.

When a number of variables associated with traffic generation are arranged by these types, several significant points become apparent as can be seen in Table 21.

Table 21 is a dramatic depiction of the marked differences between types of zones in push or propensity to produce trip volumes. The high type zones which, in toto, contain only slightly more households than the low type produce almost 2.5 times as many vehicular trips and almost 5 times as many trips among households owning two cars. The average type of zone is also of interest because it produces trips of all categories almost in an exact proportion to its number among all households. It is this fact which suggested that the proportion of potential trip-makers making trips was a good index of push.

This index of push based on the proportion of potential trip-makers making trips appears to be useful for several reasons. For one, the category of medium established a norm or average for many aspects of traffic generation measured by survey zone. This category produces both one- and two-vehicle household trips in accordance with its proportion of households in the total community. It appears to be average in the community economic-occupational level, and, in the findings recorded in Table 21, this class of zones deviates from the intermediate position expected in terms of the number of households in this category only with respect to the item "vehicular trips per developed acre." This norm, therefore, gives some suggestion both of influences which contribute to push and of the physical amount of traffic generation which develops from the present pattern of zones. Economic-occupational level is the most obvious single characteristic which distinguishes high push zones from medium and low categories. Increase of this level in a community population might be expected to increase traffic production. However, from the present data, it is not clear if the tendency of the category high in potential trip-makers who make trips to generate more traffic per household is a product simply of the higher economic resources of these households or if it also is part of the "way of life" of these households such that vehicles are used to satisfy more than an average number of trip purposes. Certainly the households in this category are more prone than others in the community to incur the costs of trip generation. In so doing they set the upper limit of the community push contained in the pattern of traffic production.

G. ECONOMIC BASE AS SOURCE OF "PULL"

What then are the dimensions of the pull which constitutes the second element in this assumed equilibrium model of traffic patterns? In a sense pull is the purpose for which a trip is made. In almost all cases the purpose is to enter into some transaction for which the member of the household gets some reward, for example, the salary or wages from appearing at the place of work, the purchases of goods or services, attendance at a school, etc. The opportunity for entering into such transactions are provided by a variety of agents throughout the community, i.e., employers, merchants, purveyors of services, social acquaintances, restauranteurs, etc. The totality of such opportunities for transactions by members of the households constitutes the pull of the community traffic system.

Consumer economics may supply the principles for understanding the conditions under which agents supply the pull opportunities for transactions by members of households. Briefly, the contribution of economic base analysis which seems to apply in this situation is the difference between the export base and the service base of a local economy. Export base economic activity involves products which are exported from the community and is, therefore, fundamental to the size, prosperity, and level of economic activity of a community. Service base economic activity involves supplying goods and services to maintain the resident population of the community.

These two kinds of economic bases, export and service, give a structure to the pull dimension of the community traffic system because they offer two distinct kinds of transactions to household members. In service base activity the members of the household are the clients or market of the agents offering transaction opportunities. Examples of such a relation are shopping, eating, personal business, etc. The export base sector of the local economy in its relation to households operates primarily as an employer and in this situation members of the household are essentially competing for employment in export base firms. This situation reverses the relation of the household to service base enterprises who are essentially competing for the household patronage.

This particular model also implies that certain associated factors will be working to influence the pattern of land use and the spatial distribution of functions in the community. For the export base enterprises, choice of location of plant is mainly influenced by considerations pertinent to a market outside the community, and in general these seem to center on accessibility of appropriate transportation facilities and utility resources. The service base enterprises, however, use a different strategy in determining place of location. Their location reflects the aim to maximize the accessibility of the place of transaction to the household clientele. Thus, there are two different tendencies at work to influence the locations at which pull of the community traffic system is to be realized. One appears to be relatively independent of the distance from a household required for the trip purpose "to work," while the other, involving most other trip purposes, operates to minimize the required length of trips from households.

The extent to which service base enterprises can locate their functions to achieve maximum accessibility is limited by the degree of specialization of their products. An item or service which by its nature is specialized, meaning that it is not regularly procured by a considerable and predictable proportion of the local population, is more likely to be offered at few locations in the community and the clientele of this item will be drawn from the whole community. By contrast an item which is standardized and is used frequently by a large proportion of the local population will be offered at many locations diffused throughout the community and will, presumably, be secured by inhabitants of the adjacent area.

Traditional examples of these two kinds of enterprises are the downtown specialty store and the neighborhood shopping center. For example, expensive women's hats and accessories will be purchased in downtown specialty stores while children's clothing and men's work clothes can be purchased at neighborhood shopping centers. It is argued by Futterman and others that there will always be a demand for specialized items and services which normally will be offered in the CBD, and that the decentralization of most commercial and other functions in present cities represents the relocation of enterprisers who are dealing with standardized items which have a broad mass market. Concerning households as clients, the pull dimension of the traffic system is apparently adjusting itself to the push dimension. It must be kept in mind, of course, that the original pattern of land use in most American cities was planned under a prevailing system of public transportation along fixed lines of access such as railroads or streetcars. The adaptation of push and pull dimensions here described probably did not become general until after World War II.

It is the fact that members of households make many short trips to secure standardized and frequently used items and services and fewer longer trips for more specialized products which indicates how the push dimension is crucial to the prediction of traffic production. For example, a member of the household makes a shopping trip to secure cigarettes and soft drinks, highly standardized items. It is predictable in most cases that the trip will be short because these products will be available within a limited distance. Supposing, however, that the household is in a new sub-division the trip, by necessity, may be longer if no stores have yet been built. It can be assumed that in time stores will be built and trip distances for shopping shortened. Push and pull in the community traffic system, therefore, are presumably components of a system tending toward equilibrium. At the moment in many communities, the push dimension is changing rapidly as the socio-economic level of an increasing proportion of the community improves. Despite this state of flux among the components, it is possible to attempt to account for traffic patterns using some of the propositions developed herein. Central to these concepts is the notion that the basic tendency of households is to maximize the proportion of household members who make trips. From this assumption a number of consequences follow, the most important being a rationale for the push-pull model of traffic patterns which has been developed above.

H. TRIP INTERCHANGE BETWEEN ZONES AS AN EQUILIBRIUM OF "PUSH-PULL"

As was previously stated, the essential features of this model as a description of patterns of community traffic generation have been expressed in various kinds of origin-destination studies. The model as described evolved in the course of the present study as a systematic description of the findings which emerged from the analysis of the Champaign-Urbana data. It further suggested several hypotheses about community traffic which could be tested with these data and thereby provide, somewhat indirectly, evidence of the possible utility of the model as description and prediction of community traffic patterns. The exploration of the applicability of the push-pull model to the findings begins with the survey results concerning traffic interchange between zones including the CBD.

The official report on the Champaign-Urbana survey prepared by the Division of Highways of the State of Illinois gives the results in the standard form which, in regard to vehicular interchange, was both tabular and cartographic.[13] Some of the propositions developed thus far in this present study suggest the underlying conditions influencing the reported traffic patterns. These propositions are: (1) volumes of vehicles on the community highway system reflect the vehicle density per acre in the survey zones and the prevailing rate of trip-making by households in these survey zones; (2) trip interchange between zones is symmetrical; and (3) trip interchange between zones follows a push-pull model, but the CBD appears to attract trips from greater distances than other zones.

The testing of the zone interchange data against these propositions was accomplished in the following manner. The interchange data in the tables noted was consolidated in the form shown in Table 22.

The problem of testing the applicability of the push-pull model to the data of the present study is complicated by two characteristics of the Champaign-Urbana community. One of these is the large proportion of households defined as student and the concentration of these households with their distinctive trip generation pattern in the survey zones about the campus. The second condition is the bifurcated CBD, and two nodes of which are roughly two miles apart. It was decided to meet these complications by making the analysis through use of the method of ranking. This method emphasizes the relations between the items compared rather than some absolute measure of attributes of items. Relativity in respect to measures of traffic generation seemed adequate in this case rather than some absolute index. The items to be analyzed were the zones contained in Table 22 and the comparison of rankings was in terms of the traits reported in the columns of the table plus zone rankings on total number of passenger trips per zone (Table 2, Appendix A). The total ranking of the number of passenger trips generated by a zone was regarded, for this analysis, as a first approximation of the relative push of the zone in the local traffic system. Pull of a zone was indicated by the difference between the ranking for total trips generated and the ranking for the total interchange with other zones reported for the zone. Rankings of zones on number of trips to the CBD and the number of intra-zone trips were also made. The procedure of this method is shown in Table 23.

Before developing implications of the results of Table 23, one further point might be made as to the pertinence of analyzing traffic data through ordinal scales such as those represented by rankings. This point concerns the fact that desire lines or tables which show the desired end of trips do not distinguish, as they are shown by present techniques in origin-destination studies, between the pull of an area and the return to an area with the purpose as "home." The return of a vehicle to its home zone is indirectly related to the push of the zone because push is an indication of the number of times the household vehicle or vehicles leave the zone. The assumption here is that all the intervening trips before the return to home are not made in the course of one round-trip. Also, if there are three-cornered trips, there are equilibrating trips to maintain the principle of symmetry of interchange between zones. This point may be clarified by examining a desire-line map and observing that while desire lines show both direction and amount of traffic between zones, they do not make clear how much of this traffic is actually returning to home.

I. TRAITS OF ZONES VARYING IN "PUSH" AND "PULL"

The differences in rankings of zones as demonstrated in Table 23 were also computed between total passenger trips and both intra-zone trips and trips to the CBD. Analyses of the results of these computations provide the following observations relative to the push-pull model. First, as results in Table 23 suggest there is a reasonably high positive correlation between the ranking of a zone with respect to the total number of passenger trips it generates, and the ranking of other forms of zone traffic production. In Table 23 barely a quarter of the zones show a marked difference, in this case nine or more rankings, between the two sets of ranks. The ten deviant cases, are, however, instructive relative to the hypothesis of push-pull in traffic generation. The six cases high in ranking on interchange trips but low in passenger trips, thus presumably demonstrating high pull, are the two CBD zones each with two immediately adjacent zones. The four zones ranking low in interchange trips but high in passenger trips and thus low in pull, were all zones on the perimeter of the internal survey area and all showed above average production of passenger trips per household. It is obvious, therefore, that the CBD area exerts unusual pull; it draws traffic from the other zones to an extent beyond what would be expected by a gravity model. In this sense these results are a kind of confirmation of the validity of the propositions entering into the push-pull model. The same results, however, raise a question unanswered by these data: Does the pull of the CBD rest in the attraction offered by the functions performed there, or could it be simply the fact that the CBD area because of its location offers maximum physical accessibility and for this reason becomes the destination of so many trips? The source of this question is the fact that only zones which are least accessible because of their location on the perimeter of the survey area which were low in pull. The differences between zone rankings in total passenger trips, trips to CBD, and intrazone trips were examined to aid in the resolution of this question.

The procedures used in Table 23 were applied to rankings of the number of trips from zones to the CBD as reported in Table 22. Here again the results indicated that for most zones the number of trips made from the zone to the CBD was proportional to the total number of passenger trips generated by the zone. The significantly deviant cases were divided into two groups of five, one for which the CBD exerted a low pull, and the other for which it showed a high attraction. The former category contained two types of zones, one producing a large number of student passenger trips relative to the number of non-student trips; the others were zones on the perimeter of the internal survey area. Apparently student households are less prone than non-student households to produce trips to the CBD. The zones for which the CBD showed high attraction were the same CBD and adjacent zones which in Table 23 had shown strong pull. This discovery was indeed puzzling because it indicated that the separated CBD's were the major destinations of each other and that some zones adjacent to the two CBD's were sending surprising volumes of traffic into the CBD's. A conclusion suggested by this finding was that the CBD and area around it becomes the focus of multi-destination traffic from the rest of the community.

J. INFLUENCES ON INTRAZONE OR SHORT TRIPS

This last conclusion was furthered from the study of the rankings of intrazone trips. This study had begun from the hypothesis that short trips would be most characteristic of zones with a high rate of trip generation by households and that these short trips would be made in or near the zone of residence. If such were the case the rankings of intrazone trips would demonstrate these zones which had a higher proportion of short trips. Again, the results did not confirm the hypothesis. Intrazone trips appear positively correlated for a high proportion of zones with total passenger trips, and the deviant cases did not show any zones with a high rate of trips per household which also ranked high in proportion of short trips. Rather, the zones which were low in intrazone trips were predominantly those containing a high proportion of student households. Either students used their vehicles only to leave the zones or else limited parking space and parking regulations within these zones discouraged intrazone trips. The zones high in intrazone trips were again CBD and adjacent zones. This fact suggests that interzone and intrazone traffic in these areas are part of the same tendency and that the pull of the CBD reflects its capacity for multi-purpose satisfaction of trip-makers. It is further suggested that perhaps a considerable proportion of short trips may be made in or about the CBD and at some distance from the zone of origin.

This analysis of the rankings of various measures of zone traffic generation gives some support to certain of the propositions of a push-pull model of community traffic. The points of interest concern mainly the pull aspects of trip-making or the flow of traffic once it is on the highway network. The push element is fundamentally represented by the proportion of households owning vehicles and the rate of trip generation per household by zone. The present analysis has shown that these traits of zones are not particularly significant in dealing with flow. For most zones it does not matter if they are proportionately large or small contributors to traffic volume. The extent of interchange with other zones, the amount which goes to the CBD, the proportion which is local, all of these indices are relatively similar in the great majority of zones, regardless of their rate of trip generation. Certain types of zones, however, such as the CBD and adjacent areas, zones with predominantly atypical households such as students, and some zones on the extreme periphery of the survey area, demonstrate characteristically different traffic patterns, i.e., deviations from the norm in number of local trips, in ratio of CBD trips, in proportion of exchange with other zones, etc. In the case of CBD zones much of this differential pattern is explained by the fact that this area, because of its functions, is a low source of initial trip origins and highly ranked as an initial destination. At the same time there is the question of the extent to which distance between zones effects the flow of travel between them. Is it possible that some proportion of the pull of the CBD is a product of its maximum accessibility to all zones? The answer to this question should further clarify the utility of the push-pull model.

K. Distance of Vehicular Travel

The matter of the place of the length of vehicular trips in any model of or general theory of community traffic is not clearly delineated. The exact influence that friction of distance exerts either in reducing trip-making or in serving as a prediction of how many trips will be made at what distance and in what type of community has yet to be specified. Measures of distance, however, are taken as a matter of course in origin-destination studies and are reported in the literature which seeks to generalize from these studies. The classic handbook of Schmidt and Campbell, Highway Traffic Estimation,[14] has shown that the length of trips to work varies considerably by size of community. The Chicago Area Study consolidated findings from three major cities to show there is rough agreement in the proportion of trips of various lengths. A number of studies have shown that there is a consistency in the variations in length of trips by purpose with journeys to work being of longer length in the same community than other purposes. The findings of the Champaign-Urbana survey were consistent with these general conclusions. The results of this survey, however, had to be stated in smaller intervals of distance because the survey area was necessarily smaller in scale than in the major metropolitan studies. The Champaign-Urbana findings are shown in Table 24.

The information in Table 24 shows the pattern of shortest trips as being markedly fewer than slightly longer trips. It then shows a progressive reduction in the number of trips as length increases. The curve represented by this distribution presumably is influenced by the size of the survey area and would, therefore, be difficult to compare to the results from the Chicago or Detroit surveys in which the internal survey included trip lengths up to fifteen miles. If it were possible to make the distribution of trip lengths into a standardized measure whereby communities of different size could be compared, then the pattern of trip lengths might contribute to a general theory of traffic. An effort was made in the present study toward such a standardization. This effort began with the fact that the smaller number of shortest trips did not seem to agree with the proposition previously expressed that maximization of the proportion of potential trip-makers who make trips would tend toward increasing the number of shortest trips.

L. COMPARISON OF TRIPS BY ACTUAL DISTANCE TRAVELED TO POTENTIAL DISTANCE FOR TRAVEL

The method which was developed was derived from the summarization of the distances between survey zones. Data on the traffic interchange between zones were available for sixty-one zones, but ten of these zones provided very little interchange. Actually, slightly more than 100 pairs of zones exchanged trips. The actual distance in half-miles between the geographical centers of each of these 100 pairs of zones was computed and summarized in Table 25. This distribution shows the range in distances between zones, and it is noteworthy that the shortest distances are fewer in number than the medium-length distances. This fact suggests that the reason the shortest trips were fewer in number than longer trips perhaps might be due to the fact that a driver actually has fewer choices in short distances to travel to another zone than he has in medium-sized distances. This possibility was tested by dividing the number of trips shown in Table 24 by the number of distances between pairs of zones interchanging traffic with each other. The result of this calculation is shown in Table 25.

The series of figures in column 4 of Table 25 is not only practically linear in respect to the ratio of distances to trips, but it suggests a standardized formula which might hold in the relation of these variables in any community. It also suggests that the possibility of making the shortest trips is much higher than making medium or longer trips when allowance is made for the actual number of possible interchanges available to a trip-maker at these various distances of zones from each other. Table 25 introduces, through consideration of the actual number of distances involved in potential interchange between zones, a concept usually ignored in the discussion of interchange.

M. A THEORY OF THE VOLUME OF AND DISTANCE TRAVELED BY TRAFFIC

These various findings, relative to distance traveled by trip-makers as related to the number of destination zones at various distances from the origin zone, suggest a general theory covering length of trip as reported in the Champaign-Urbana study and which may pertain to traffic in other communities. The elements of this theory are: (1) the propensity to make trips appear to be most closely linked to the characteristics of households comprising the survey zones; and (2) once vehicles are committed to the highway system the distance they will travel to a destination is a linear function of the number of distances to all other zones. This array of distances is a function of the scale of size of the community or, more correctly, the scale of the survey area. It is possible, therefore, that the clear linear relation between the distance traveled by trip-makers and the ratio of the actual distances between paired zones and the number of trips made between these zones would hold in any community regardless of its size.

The reasoning behind this theory is somewhat different from that developed in the Chicago area study as "A Descriptive Theory of Urban Travel,"[15] for it assumes that the original volume of trips produced by a zone is a function of the socio-economic level of the households in the zone. The distances that the vehicles making these trips will travel is a direct function of the array of distances which confront the trip-maker when this array is calculated in terms of the scale of distances between all zones in the community. The trip-makers of each zone, of course, are confronted with an almost unique set of distances to other zones. The theory presented here is simply a way of estimating the total volume of trips by distance traveled, and if this theory were to predict future traffic patterns it would also have to account for the direction of trips to other zones as well as the distance to be traveled. The present theory assumes that direction is also a function of the array of distances to other zones available to the trip-maker, although the question of direction of travel was not explored in the present study other than in the analysis of trips to the CBD.

Also, caution should be noted concerning the adequacy of the Champaign-Urbana survey data as the ground for the theory of traffic outlined above. This reservation rests on the premise that the data of Table 25 represent only distances between pairs of zones between which exchange took place. Actually, the distances should be calculated for the distances between all zones in the survey area on the assumption that there is a possibility of exchange of traffic between all combinations of pairs of zones in the survey area. This possibility, however, did not exist in the Champaign-Urbana survey because at least a dozen zones contained such small populations that it would not have been possible to assume a probability of interchange with all other zones, except, perhaps, according to some random pattern. The conditions necessary for the proper grounds of the theory outlined above would be that all zones contained proportionately large traffic-generating populations and were relatively equal in size.

N. SUMMARY

(1) The problem treated in this chapter was that of constructing a model or theory of community traffic generation which incorporated the present findings concerning socio-economic influences on trip-making into a form containing physical measures of traffic volumes such as the number of vehicular trips per survey zone acre and the length of vehicular trips. The physical measures considered included the number of passenger trips, vehicular trips, vehicles, and households per developed acre by zone. Summaries of length of trips were mainly in terms of the numbers of trips involving interchange between pairs of zones throughout the survey area.

(2) The Pearsonian coefficients of correlation between the number of vehicles and the number of vehicular trips by survey zone and between the number of households and the number of vehicular trips by zone are reduced when these same correlations are computed in terms of number of vehicles, vehicular trips, and households per acre. This finding suggests measures of traffic generation stated as densities per survey zone acre and appears to introduce intervening variables or conditions which actually reduce correlation coefficients between the items involved. The conditions producing these unanticipated results do not seem to be simply a statistical artifact produced by a skewed distribution in the sizes of survey zones as measured by number of developed acres. Rather, the findings indicate that there is not a linear relation between the density of either households or vehicles per acre and vehicular trips per acre because the zones with both the highest and lowest rates of trip generation, as measured by the proportion of potential trip-makers making trips, had comparably low rates of vehicular trips per acre. Zones with only average rates of trip-making measured by potential trip-makers making trips had the highest vehicular trips per developed acre. This disparity is apparently the reason for the reduction of statistical correlation when

traits associated with traffic production are expressed in density per acre.

(3) The number of developed acres per zone appeared to give a more accurate prediction of the total number of trips which would be generated by vehicles garaged in the zone than did the number of acres officially zoned as residential. The reason for this condition is apparently that the areas of a survey zone which are officially designated as residential are not actually inclusive of all households in a zone.

(4) The range in the average number of vehicular trips per developed acre indicates that the zones which are most productive of vehicular trips generated ten to twelve times as many trips per acre as the least productive zones. The actual number of vehicular trips per acre for each of the survey zones could not be estimated accurately because of the difficulty in determining the sampling error by zone and in allocating to student households the proportion of traffic which they generated per acre. Because of these difficulties the method developed for making a gross estimate of the total volume of traffic generation on the basis of densities per acre of survey zone characteristics could not be confirmed by comparing the results of the method against the traffic volumes reported from the roadside survey. The deviation of the results obtained by the method from the observed traffic volumes was not, however, appreciably different from those obtained by the household survey prior to their correction through an expansion factor. The actual sources of this discrepancy in the Champaign-Urbana survey might not be present in other communities where this method could be employed.

(5) Zones high in vehicle trip generation per acre were relatively similar in land use and population characteristics. Those zones relatively low in trips per acre constituted a heterogeneous category in respect to land use and population. Zones with high trip production per acre were not, however, zones showing the highest rate of trip generation per household by survey zone.

(6) Length of trips was analyzed to develop estimates of traffic interchange between zones in order to lay the ground of a general theory describing physical and social parameters involved in traffic volumes and flow within a community. A "push-pull" theory was propounded which regarded the prevailing pattern of interchange between zones as an equilibrium between pull and push factors present in the relation between every pair of zones. The total volume and flow of traffic in a community is the sum of these paired equilibria. Pull is the attraction of zone represented by the purposes to be satisfied by making trips to the zone. Push is defined

as the tendency of households to maximize the proportion of potential trip-makers who make trips. The equilibrium of zone interchange is regarded as the number of trips of various lengths with which a maximum number of potential trip-makers travel the minimum distances necessary to satisfy their purposes. It appears that as the number of trips per household increases the proportion of potential trip-makers making trips increases, and that the proportion of all household trips which are shorter in length also increases. Therefore, according to the push-pull theory the number of trips in the distribution of all community trips should be inversely proportional to the length of trips.

(7) Testing of the applicability of the push-pull model to the findings of the Champaign-Urbana survey was complicated by the presence of the bi-partite CBD and the concentration of student households in a number of zones. The complication created by student households was a pattern of traffic generation different from that of the non-student sample. The possible influences of these two complicating factors was analyzed by studying the the numerical ranking by zones of volumes of traffic generated by each. The number of intrazone trips in each zone was also examined. The analyzing of the findings from these operations indicated that for slightly more than three-quarters of the zones there was a high correlation of total volume of trips with specific kinds of trips, such as intrazone and trips to CBD. The push-pull of these zones appeared to be in balance. A number of zones, however, demonstrated deviant traffic patterns. These included the CBD area which was high in pull and low in push; certain zones on the periphery of the survey area which were the opposite of the CBD in respect to pull and push; and zones with a concentration of student households which produced low numbers of intrazone trips. The CBD produced proportionately a number of intrazone and short trips. The CBD area appears to be the destination of much traffic which was multi-purpose in nature.

(8) Tabulation of interchange traffic by length of trip indicated the assumption of the push-pull model that shorter trips would be greater in number than longer trips did not hold for the categories of shortest trips. When, however, the distances between all pairs of zones involved in traffic interchange were tabulated, it appeared that the number in the category of shortest length of trip was also fewer than the number in some classes of longer trips. In short, the actual possibilities of making shorter trips was less than that for categories of longer trips. Therefore, the number of trips in each category "length of trip" was divided by the number of actual distances between pairs

of zones which were of the same length. The series of ratio secured by this operation was approximately linear and all ratios representing shorter trips were greater than ratios representing longer trips. This finding appeared consistent with the push-pull model of traffic volume and suggested a standardized method for comparing the findings from origin-destination studies made on communities different in size of survey area. ●

VI. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This chapter treats the general conclusions of the study as they concern the central goals of the research and analysis undertaken on the basis of the information supplied by the Champaign-Urbana origin-destination survey. The specific findings and conclusions relative to discrete problems in the successive steps of the study have been summarized at appropriate points at the end of Chapter III, IV, and V. Selected items from these summaries will be included in the present chapter where they are pertinent to an over-all recapitulation offering answers to the initial questions posed by the study as noted in Chapter I, the Introduction. These final conclusions will bear on these original issues concerning socio-economic factors in traffic generation and will suggest further research which appears necessary to provide greater understanding and explanation of the problematic issues concerning community traffic as they have emerged from the present study.

The original purpose of this study was to use the results of the Champaign-Urbana survey to develop some theoretical propositions about the social influences on traffic generation. These findings were expected to have some application to the practical problems of community traffic engineering insofar as such activities utilize origin-destination data. Another basic interest of the study concerned the possibility of identifying data which might be available to the student of traffic generation as a substitute for the costly origin-destination survey as it has been developed under the stimulus of the Bureau of Public Roads. However, once the study had begun to make progress, it became apparent that the latter interest in developing sources of information as alternatives to the origin-destination survey depended upon solving the former interest in factors influencing or explaining community traffic. The conclusions of the study, therefore, aim to set forth certain parameters which seem relevant in either explaining or understanding community traffic generation, and then suggesting the kind of data which might be secured relative to these parameters by some method other than the origin-destination survey. It should also be kept in mind in regard to these conclusions that they involve data developed from the conditions in a medium-sized city. The aim of these conclusions is to express the findings in their most generalized terms. For this reason attention has been paid to the correspondence of its findings with major investigations such as the Detroit and Chicago surveys. The fact, however, that these conclusions refer to a smaller city may well limit their generality.

A. PROPORTION OF HOUSEHOLDS PRODUCING TRIPS

The study began from the presumption that the household, as the fundamental unit in the internal survey, could be profitably analyzed in terms of its contribution to traffic generation. The original analysis of the data treated the separate households reported in the sample of households interviewed as part of the internal survey. This analysis revealed a broad range in the distribution of passenger trips by households in the sample. The range and skewness of this distribution is recapitulated in Table 26.

This table reveals the considerable range in production of trips by separate households and shows clearly the skewness upward of this distribution. One measure of the degree of skewness is that the households generating four or less trips included about 36 per cent of all households in the sample. Yet these households produced only 8 per cent of all passenger trips, a figure roughly equal to the proportion of all passenger trips made by sample households producing twenty-five or more trips. These households accounted for only 2.3 per cent of sample households. Thus, traffic generation shows great variation by households; its distribution is not in the form of a normal or bell shaped curve. This face suggests that an arithmetic mean is a poor measure of the central tendency of a distribution of trip production by households.

B. RANGE BY SURVEY ZONES OF AVERAGE NUMBER OF TRIPS PER HOUSEHOLD

A considerable variation in trip generation is also observed when measures of trip production by household are computed on the basis of survey zone averages for trips per household. The procedure of computing measures of traffic on indices per zone appeared justified in this study after calculations indicated that most zones revealed greater homogeneity in socio-economic traits than heterogeneity. Also, a two-way analysis of variance of trip production as correlated with number of vehicles indicated that differences between all survey zones with regard to trip production was greater between zones than within zones. For these reasons the use of zone averages as measures of socio-economic characteristics to be correlated with trip generation appeared feasible. The zone medians of trips per household were used in a number of calculations as measures in order to compensate for the known skewness of the distribution of trips by households. Table 27 shows the median number of trips per household per zone.

This table demonstrates that there is not only considerable variation in trip production by survey zones as a whole, but that the distribution of zones shows with respect to trip generation a more normal curve than the whole sample of households. Since it has been demonstrated that zones tend toward homogeneity, this distribution of zone medians cannot be attributable solely to sampling error, if the zones are regarded as samples of the traffic-producing universe represented by a community. In terms of the conclusions to be developed, there is no reason to assume that the distribution of zones in a community would show in the pattern of zone averages in a normal curve. Explanation of this distribution is attributed, as noted below, to the fact that traffic generation within the physical area of a community involves the interaction of a variety of forces and influences.

C. FACTOR ANALYSIS AND MULTIPLE CORRELATION OF TRIPS AND HOUSEHOLDS

A number of measures, including Guttman-type scales, were developed to describe socio-economic and occupational characteristics of households and survey zones. These measures were related to various indices of traffic generation through the procedure of factor analysis. All of the measures used in this analysis were stated as rates or summarizing characteristics for survey zones. The factor analysis indicated that the socio-economic level of a household as measured by zone indices was the one element most closely related to rate of traffic generation by zones. As a single factor it accounted very clearly for more variance in the rate of traffic generation than any other dimension of community traffic as it was described by variables in the study. This same analysis, however, indicated that the production of community traffic is apparently a complex phenomenon, and no single influence accounts statistically for at least a majority of the volume of traffic generation.

It was also possible on the basis of the matrix of correlations used to develop the factor analysis to prepare a multiple correlation involving three variables which served best to predict the rate of household traffic production by survey zones. These variables were occupational level, value of residential structure, and value of make of vehicle. Distance from CBD was part of this complex of traits; however, it contributed proportionately very little to the prediction of trip generation when allowance was made for the influence of the other three variables. These items provided for a multiple correlation only of the order of .80. These measures are clear indicators that socio-economic level is the dimension of households most clearly associated with trip generation, but as predictors of trips, they account for barely two-thirds of the variance. It appears that other influences also operate in trip production of households measured by zones.

D. TRAFFIC GENERATION BY ONE- AND TWO-VEHICLE HOUSEHOLDS

One such condition which compounds the measurement of influences producing household trip generation is that households may possess two or more vehicles. Roughly 15 per cent of all households in the survey sample were two-vehicle units. The variation between survey zones in respect to the per cent of households having two vehicles, however, is considerable, as is shown by Table 28.

The proportion of two-vehicle households in survey zones increases as the socio-economic level, the per cent of households containing vehicles, and the distance from CBD increases, although these three measures may be independent of each other to some degree. Most characteristically the two-vehicle household is found in zones of higher socio-economic level, hence, as a trait it is also closely linked to the major influence on the rate of trip-making itself: socio-economic level of household. Doubling the number of vehicles in a household, from one to two, does not double the traffic generation by the household. In terms of vehicular trips, all two-vehicle households, on the average, make approximately only one-third more vehicular trips than single-vehicle households. This should be kept in mind in estimating future traffic volumes on the basis of the number of vehicles based in an area. The proportion of vehicles in one- and two-vehicle households, not the number of vehicles itself, is the best basis for estimating the relation between vehicles and rates of trip-making by zones. Table 28 indicates that the possible increase in two-vehicle households could be very great if the present trend in multi-vehicle ownership by households continues.

E. POTENTIAL TRIP-MAKERS AS AN INDEX OF TRIP PRODUCTION

The findings of the present study suggest that one of the criteria of households most useful for interpreting the influences on traffic generation is the proportion of potential trip-makers who make trips (see Table 20). This index or ratio can be applied to a variety of household indices. For example, in one- and two-vehicle households the rates of trip generation are more alike for two-vehicle households than for one-vehicle households when allowance is made for proportion of potential trip-makers making trips. This point is illustrated in Table 29. In this table three types of survey zones are compared in trip-production. These types represent zone low, medium, and high in proportion of potential trip-makers making trips.

Table 29 is of special interest because it gives some comparison of the consequences of the two principal procedures by which households increase their rate of trip production. One is the addition of a second vehicle; the other is the intensified use of the vehicle or vehicles in the household. Column 2 indicates that there is relatively limited variation in the rate of trip generation for two-vehicle households and that, perhaps, about nine vehicular trips per household over a twenty-four hour period is an average of the upper limit to be expected per household. The variation in single-vehicle households is much greater with high trip-generators producing on the average 1.5 times as many trips as low trip producers. Table 29 also indicates that the largest number of trips are produced by the medium-type household classified by potential trip-makers making trips. This suggests that the potential for increasing the total rate of trip generation in the community is greater than would be the case if a larger proportion of households were already in the high trip generating category.

F. THE "PUSH-PULL" MODEL OF TRAFFIC GENERATION

The general theory of community traffic volumes which appears to apply to the findings from this study can be referred to as a "push-pull" theory or model. Push is the rate of trip generation by the households of the community. The higher the socio-economic level of the household, the more trips made. Pull is the attraction of some area in the community to satisfy the purposes for which the trip is made. The more specialized the purpose of the trip, the longer the trip will be. Areas with specialized attraction should draw from greater distances. Attraction, represented by the land use of an area, can be distinguished as land use involving export base functions and service base functions. The purpose of most trips to places characterized by export base activity are trips to work. These will be longer on the average than trips to places specializing in service base activity. If the patterns of community traffic volumes are regarded as an equilibrium of these push-pull influences, local traffic generation might be defined as a system which tends to maximize the proportion of potential trip-makers who make trips and to minimize the distances traveled in such a system. To accomplish this allowances must be made for the number of destinations, represented by zones, at various distances from all possible origins.

The utility of such a theory to those interested in problems of community traffic would be enhanced if rates of traffic generation could be reduced to some physical measures such as trips per acre. Such measures give a more precise description of the traffic generated by the various sectors of the community as they are served by the local roadway system.

G. HOUSEHOLD DENSITIES AND TRIPS AS A METHOD OF ESTIMATING COMMUNITY TRAFFIC

An attempt was made to restate the findings of the study describing the socio-economic traits of households associated with traffic generation to rates of trip-making per acre of survey zones. A series of calculations indicated that when items such as number of vehicles and number of trips were correlated as trips per acre with vehicles per acre, the levels of statistical correlation were reduced. The reason for this reduction was that zones highest in trip production per household were not the highest in trip production per acre. The major cause of this condition appears to be that zones varied considerably in density of households per acre with zones both high and low in trip generation having somewhat similar households per acre ratios. For these reasons it did not appear feasible to convert the findings concerning the relation of household characteristics to some ratio of households to acres.

It was possible, however, to state the differences in the traffic producing potential of survey zones to an acre basis (see Table 19). The distribution of the number of trips per acre by zone shows a considerable number of cases at extreme values, although these is also observable central tendency. Estimates of the actual generation of trips per acre per zone was not possible because of the nature of the sampling design in the survey. The estimate based on acres of the number of trips generated by the whole survey area utilized the over-all average. This estimate produced a figure for the number of vehicular trips for the whole community which was considerably less than that indicated by the cordon line count in the original survey. The method of estimating the total volume of internal trips from the average number of trips reported per household per acre did appear feasible, provided some estimate could be made of the actual population of the survey zone. The findings for Champaign-Urbana suggested that the zones on the average produced approximately twelve vehicular trips per developed acre. There was a considerable range in production of vehicular trips by zone, ranging from less than three per developed acre to about twenty-five. It might be expected that other communities with higher residential density would show a greater range in the production of trips per acre. It is this range or variation in trips per acre in a community which complicates the procedure of estimating total traffic volume on the basis of rates of vehicular trips per acre.

H. LENGTH OF TRIP AND ZONE INTERCHANGE

Length of trip was analyzed in terms of the interchange between zones and the distances between pairs of zones. When allowance was made for the number of distances between zones, the reported interchanges showed a clear negative relation between the number of vehicular trips and the distance traveled. It appears not unlikely that the number of distances between the zones in a community is a constant which would be used in comparing the distribution of distances traveled by vehicles in communities of different sizes.

The total volumes of traffic and the amount of interchange for survey zones were studied to determine if zones demonstrated an equilibrium of push-pull with respect to traffic generation. Rankings by number of trips produced by zones were used for this analysis. They indicated that about three-quarters of the zones were relatively equal in push and pull. The main exceptions to this equilibrium were zones either containing or close to the CBD which were high in pull, and some zones on the periphery of the survey area which were low in pull. The implication of these findings seems to be that the distances vehicles travel from a zone are more influenced by the location of the zone relative to other zones than by the household composition of the zone. In general, zones demonstrate similar patterns of length of trips whether they represent high or low production of trips per household.

The most general conclusion of the study is that the socio-economic level of the households in a zone are the main determinant of variations in the rate of trip production by zones. The density of households in the zone is a secondary factor whose influence is expressed in combination with the first determinant. The numbers of trips of various lengths from a zone is directly proportional to the number of varying distances to other zones. In this sense, therefore, the direction and length of trips from a zone apears to follow a predominantly physical principle, while the actual volume of and rate of generation of trips appears to be more influenced by socio-economic considerations.

I. SUGGESTIONS FOR FURTHER RESEARCH

The various findings and conclusions noted above indicate the need for further research to confirm their applicability to communities other than Champaign-Urbana, and to demonstrate the utility of information sources which would serve as substitutes for origin-destination surveys. Such research, however, might be conducted with the results of already completed origin-destination surveys on communities for which other pertinent kinds of data were available. The basic aim of such research would be to determine whether the parameters of traffic generation developed by the present study apply to other communities. For example, is the range of the distribution of vehicular trips by household relatively constant among communities? Is the distribution of the average number of trips per survey zone similar? What is the range in the number of vehicular trips made by households per acre, and is the proportion of potential trip-makers who make trips approximately the same? Such comparisons are possible for the findings of origin-destination surveys which have been reported in terms of the traffic-generating traits of survey zones.

Once the comparability of these measures as developed in the present study has been established relative to other studies, the next step is to develop indices of socio-economic levels of households and zones in order to test the central finding that these levels are highly correlated with traffic generation. It should be noted that all communities equal in size or larger than Champaign-Urbana have been tracted for the U.S. Census. Information is, therefore, available on income and economic levels. Champaign-Urbana was tracted only after the present analysis was completed, thus it was necessary for the project itself to develop measures of socio-economic level. If Census data were to show high correlations with the parameters of traffic generation, it might conceivably serve as one type of substitute for an origin-destination survey in which there is an interest in the total expected volumes of traffic. It might even be possible to analyze Champaign-Urbana traffic according to the Census information now available by tracts.

The investigation of trip generation per acre of residential areas should be pursued for its utility in the practical problems of traffic engineering. There are difficulties in establishing vehicular densities by acre because of the sampling procedures used in origin-destination surveys. The use of automobile registration data as a substitute for the household survey might be explored. This possibility was not pursued in the present study due to the large number of student vehicles which would have been registered in counties and communities outside of Champaign-Urbana. The influence of multi-family residence, especially on trip production per residential acre, should be explored. The present study found that the highest production of trips per residential acre was by zones of predominantly single-family residences. There were, however, no survey zones which were largely multi-family dwellings, therefore no control for this condition could be developed. The increasing tendency in many communities to construct high-rise residential apartments in peripheral areas which traditionally have been low density single-family residential zones promises a new source of trip generation. This condition could be analyzed within the framework provided by the present study.

The relation between the number of trips of varying lengths to the number of actual physical distances should be examined to ascertain if this relation is constant in all communities. Such an analysis requires data on the interchange between zones. Where such information is available, it might be possible to compare the predicted results from the kind of push-pull model of traffic generation posited in the present study to observed interchange reported in surveys.

Some research should be directed to the question of the influence of improvement of the total community socio-economic level. As such an increase occurs as part of the general growth of the Gross National Product, it should, if the present conclusions are valid, lead to an over-all increase in the traffic generation by all segments of the community. This increase could be presumed to occur even if the present proportions of local households at each socio-economic level remain constant. Associated with this question is the matter of the contribution of the two-vehicle or multi-vehicle family. The increase in the number of such families appears certain, and as this ample of vehicle-owning households becomes larger, it may be possible to make more precise estimates of its potential for traffic generation.

Finally, the present study suggests a rather unusual condition which may exist in some cities, especially those the size of Champaign-Urbana. This condition is the presence of a specialized population whose pattern of traffic generation may be diverse from that of majority of the local population. In Champaign-Urbana the students of the University of Illinois constituted such a population, and any understanding of, or planning for, the local traffic system would have to allow for their distinctive pattern of trip-making. Communities with large specialized vehicle-using populations, for example, armed forces centers, tourist-oriented places, governmental institutions, etc., may contain conditions for which general principles may not apply. All of the above problems and issues for investigations should be examined to make possible applications of the findings of the present study.

J. SUMMARY

The following statements are presented as a brief and essentially cursory summary of the salient findings of the study.

(1) The range of the distribution of number of passenger trips as classified by proportion of households making this number of trips was very considerable, actually from zero to over thirty trips. The distribution was skewed upward and this condition suggests that the arithmetic mean is not representative of the central tendency of such distributions.

(2) There is statistical and other evidence that certain measures of traffic generation such as the number of trips per household can be calculated as averages of the survey zones which are statistically representative of the characteristics of the zones.

(3) The range of the distribution of the median number of trips per household per zone is considerable, from zero to nine, but this distribution tends toward a more normal curve.

(4) Socio-economic level of households, as estimated per survey zone, showed relatively high association with trip generation by zone. A multiple correlation using such measures of socio-economic level accounted for about two-thirds of the statistical variance between these variables.

(5) Although the socio-economic level of a household is most highly associated with trip generation by survey zone, traffic generation appears to be a multi-factor phenomenon in which other influences were not clearly delineated in the present study.

(6) Two-vehicle households produce, on the average, only one-third more vehicular trips than one-vehicle households, and in the present study about 15 per cent of households contained two-vehicles. Increase in the number of vehicles in a community need not, therefore, increase vehicular trips proportionately if there is any tendency for additional vehicles to be acquired by households already possessing one.

(7) The proportion of potential trip-makers who make trips in a survey zone appeared to be the most diagnostic measure for purposes of identifying households differing in trip generation. The range by survey zones in proportion of potential trip-makers making trips was from approximately 30 per cent to 74 per cent.

(8) The continuing pattern of community traffic volumes and flows apparently could be described as a "push-pull" model representing an equilibrium between the push of household trip generation and the pull of trip purposes to be satisfied by land uses

distributed at varying distances from households.

(9) Trip generation by household was reduced to trips per survey zone acre as produced by households in the survey zone; however, zones producing most trips per acre were not identical with zones highest in trip production by households. The range in trips per acre produced by the households of the survey zones was estimated to be approximately from three to twenty-five.

(10) Relatively precise information on the number of trips per acre generated by the households of survey zones should provide an estimate or prediction of total community traffic generation if difficulties presented by origin-destination sampling procedures can be overcome.

(11) The distribution of distances traveled from the zone of origin appeared to be directly proportional to the number of distances of all survey zones from one another. Distance traveled, therefore, appeared limited by a physical dimension while generation of trips appeared to be a product of socio-economic influences.

(12) Further research, utilizing results of origin-destination surveys of other communities, and appropriate information such as the U.S. Census, is necessary to determine whether these findings apply to other communities.

VII. APPENDICES

A. CHARACTERISTICS OF HOUSEHOLD SURVEY ZONES

This section consists solely of the following tables:

Table A1. Developed Acres, Student and Non-Student Households by Survey Zones

Table A2. Numbers of Vehicles and of Passenger Trips of Student and Non-Student Households by Survey Zones

Table A3. Number of One- and Two-Vehicle Families and Number of Vehicular Trips of Zones

Table A4. Survey Zones Reported In Household Interview Sample and Not Used in Analysis

Table A5. Selected Social Characteristics and Measures of Traffic Generation by Non-Student Household by Survey Zone

Table A6. Selected Social Characteristics and Measures of Traffic Generation by Student Households by Zones

Table A7. Land Use of Total Developed Acres Per Survey Zone

Table A8. The Distribution of Occupations of Drivers of Vehicles Without Passengers by Survey Zone

Table A1

DEVELOPED ACRES, STUDENT AND NON-STUDENT HOUSEHOLD BY SURVEY ZONES

Number of Households

Zone	Total Developed Acres	Per Cent	Student	Per Cent	Non-Student	Per Cent	Total	Per Cent	Zone Composition
101	51	.8	* 1	.05	14	.70	15	.38	N.S.
121	169	2.5	24	1.25	68	3.41	92	2.35	Mixed
122	293	4.4	16	.83	91	4.56	107	2.74	Mixed
123	52	.8	14	.73	12	.60	26	.67	Mixed
124	320	4.8	* 9	.47	76	3.81	85	2.18	N.S.
125	300	4.5	14	.73	82	4.11	96	2.46	Mixed
126	237	3.6	* 2	.10	35	1.76	37	.95	N.S.
128	140	2.1	* 4	.21	36	1.81	40	1.02	N.S.
131	173	2.6	18	.94	69	3.46	87	2.23	Mixed
132	126	1.9	28	1.46	72	3.61	100	2.56	Mixed
133	212	3.2	19	.99	95	4.76	114	2.92	Mixed
134	177	2.7	10	.52	63	3.16	73	1.87	Mixed
135	146	2.2	* 2	.10	13	.65	15	.38	N.S.
136	189	2.8	* 6	.31	80	4.01	86	2.20	N.S.
141	365	5.5	--	.00	12	.60	12	.31	N.S.
142	100	1.5	* 3	.16	43	2.16	46	1.18	N.S.
143	161	2.4	10	.52	58	2.91	68	1.74	Mixed
144	177	2.7	11	.58	49	2.46	60	1.54	Mixed
145	105	1.6	10	.52	20	1.00	30	.77	Mixed
146	73	1.1	--	.00	11	.55	11	.28	N.S.
152	124	1.9	427	22.32	43	2.16	470	12.03	Mixed
153	21	.3	50	2.61	** 6	.30	56	1.43	S.
154	156	2.3	92	4.81	55	2.76	147	3.76	Mixed
155	111	1.7	14	.73	42	2.11	56	1.43	Mixed
156	185	2.8	* 2	.10	69	3.46	71	1.82	N.S.
202	52	.8	74	3.87	** 6	.30	80	2.05	S.
203	120	1.8	261	13.64	48	2.41	309	7.91	Mixed
204	129	1.9	106	5.54	--	.00	106	2.71	S.
205	114	1.7	196	10.25	25	1.25	221	5.66	Mixed
301	69	1.0	15	.78	34	1.71	49	1.25	Mixed
311	191	2.9	93	4.86	101	5.07	194	4.97	Mixed
312	49	.7	172	8.99	24	1.20	196	5.02	Mixed
313	239	3.6	76	3.97	88	4.41	164	4.20	Mixed
321	205	3.1	22	1.15	110	5.52	132	3.38	Mixed
322	211	3.2	22	1.15	91	4.56	113	2.89	Mixed
324	292	4.4	* 9	.47	46	2.31	55	1.41	N.S.
333	81	1.2	* 1	.05	9	.45	10	.26	N.S.
341	61	.9	--	.00	7	.35	7	.18	N.S.
342	99	1.5	11	.58	29	1.45	40	1.02	Mixed
344	29	.4	--	.00	7	.35	7	.18	N.S.
351	89	1.3	* 6	.31	25	1.25	31	.79	N.S.
352	191	2.9	* 1	.05	26	1.30	27	.69	N.S.
353	170	2.6	* 6	.31	56	2.81	62	1.59	N.S.
361	101	1.5	56	2.93	48	2.41	104	2.66	Mixed
44	6,655	100.0	1,913	100.00	1,994	100.00	3,907	100.00	

N = 41 for Non-Student Calculations N = 27 for Student Calculations

Zones Added in the Analysis of Number 2 Cards

129	98	1.4	* 1	.05	7	.35	8	.20	N.S.
331	106	1.5	--	.00	8	.40	8	.20	N.S.
332	58	.8	--	.00	4	.20	4	.10	N.S.
	6,917	100.0	1,914	100.00	2,013	100.00	3,927	100.00	

* = Counted in Non-Student Population ** = Counted in Student Population

Table A2

NUMBERS OF VEHICLES AND OF PASSENGER TRIPS OF STUDENT AND NON-STUDENT HOUSEHOLDS BY SURVEY ZONES

	Total Vehicles Per Zone			Total Passenger Trips		
Zone	Student	Non-Student	Total	Student	Non-Student	Total
101	--	6	6	--	25	25
121	20	73	93	114	391	505
122	17	102	119	94	661	755
123	14	9	23	86	50	136
124	--	117	117	--	593	593
125	15	104	119	47	465	512
126	--	45	45	--	237	237
128	--	43	43	--	302	302
131	15	60	75	85	306	391
132	26	73	99	142	382	524
133	17	117	134	62	612	674
134	10	69	79	38	430	468
135	--	16	16	--	78	78
136	--	97	97	--	575	575
141	--	10	10	--	50	50
142	--	49	49	--	271	271
143	10	63	73	43	328	371
144	11	52	63	50	332	382
145	9	20	29	45	121	166
146	--	12	12	--	65	65
152	175	37	212	888	187	1075
153	20	--	20	51	--	51
154	41	48	89	167	234	401
155	6	25	31	16	162	178
156	--	44	44	--	336	336
202	12	--	12	92	--	92
203	111	38	149	585	156	741
204	14	--	14	135	--	135
205	31	9	40	287	24	311
301	12	23	35	61	124	185
311	56	97	153	284	498	782
312	78	14	92	309	87	396
313	41	92	133	222	560	782
321	21	123	144	107	661	768
322	21	99	120	105	608	713
324	--	74	74	--	400	400
333	--	12	12	--	56	56
341	--	4	4	--	32	32
342	10	32	42	64	159	223
344	--	10	10	--	48	48
351	--	28	28	--	149	149
352	--	29	29	--	157	157
353	--	47	47	--	278	278
361	30	42	72	156	237	393
44 Zones	843	2,064	2,907	4,335	11,427	15,762

N = 41 for Non-Student Calculations   N = 27 for Student Calculations

Zones Added in the Analysis of Number 2 Cards

129	--	9	est.9	--	56	56
331	--	6	est.6	--	24	24
332	--	3	est.3	--	16	16

Table A3

NUMBER OF ONE- AND TWO-VEHICLE HOUSEHOLDS AND NUMBER OF

VEHICULAR TRIPS BY ZONES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
121	38	16	54	70	30	14	68	56	24
122	63	18	81	78	22	10	91	69	20
124	49	28	77	63	37	7	84	58	33
125	54	25	79	68	32	3	82	66	30
126	29	8	37	78	22	0	37	78	22
128	32	4	36	89	11	4	40	80	10
131	44	5	49	90	10	20	69	64	7
132	49	12	61	80	20	11	72	68	17
133	60	27	87	69	31	8	95	63	28
134	44	11	55	80	20	8	63	70	17
135	12	2	14	86	14	1	15	80	13
136	68	13	81	84	16	5	86	79	15
142	34	6	40	85	15	6	46	74	13
143	42	7	49	86	14	9	58	72	12
144	42	5	47	89	11	2	49	86	10
145	16	2	18	89	11	2	20	80	10
146	8	2	10	80	20	1	11	73	18
152	33	2	35	94	6	8	43	77	5
154	36	2	38	95	5	17	55	65	4
156	40	2	42	95	5	29	71	56	3
203	36	1	37	97	3	11	48	75	2
301	14	3	17	82	18	17	34	41	9
311	59	14	73	81	19	28	101	58	14
312	12	1	13	92	8	11	24	50	4
313	64	14	78	82	18	10	88	73	16
321	81	15	96	84	16	14	110	74	14
322	73	13	86	85	15	5	91	80	14
324	33	17	50	66	34	5	55	60	31
333	8	2	10	80	20	0	10	80	20
342	22	2	24	92	8	5	29	76	7
344	4	3	7	57	43	0	7	57	43
351	14	5	19	74	26	12	31	45	16
352	18	5	23	78	22	4	27	67	19
353	40	1	41	98	2	21	62	65	2
361	31	4	35	89	11	13	48	65	8
Sub-Total	*1,302	301	1,599			321	1,920		
Total	**1,365		1,662			380	2,024		

* Includes only zones having both one- and two-car families.

** Adds information calculated for zones having only one- and zero-car families (101, 123, 141, 155, 205, 341) and zones added to the study (129, 331, 332) in the analysis of number 2 cards.

(1) Zone number
(2) Number of one-car families per zone
(3) Number of two-car families per zone
(4) Total number of one- and two-car families per zone
(5) Per cent of one-car families of total number one- and two-car families per zone
(6) Per cent of two-car families of total number one- and two-car families per zone
(7) Number of zero-car families per zone
(8) Total families per zone
(9) Per cent of one-car of total families per zone
(10) Per cent of two-car of total families per zone

Table A3 (continued)

(1)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
121	3	5	192	74	83	32	381
122	5	6	286	147	143	64	640
124	4	9	237	91	165	100	593
125	4	8	202	67	129	49	447
126	2	3	129	37	38	6	210
128	2	1	170	76	9	10	265
131	3	2	166	80	25	8	279
132	4	4	217	94	53	24	388
133	4	9	217	141	198	47	603
134	3	4	170	71	57	29	327
135	1	1	21	27	6	5	59
136	5	4	278	166	71	26	541
142	2	2	93	49	19	12	173
143	3	2	145	76	37	14	272
144	3	2	165	82	23	15	285
145	1	1	61	25	18	10	114
146	1	1	19	9	9	2	39
152	2	1	87	45	9	4	145
154	3	1	99	54	27	10	190
156	3	1	150	85	9	13	257
203	3	0	37	29	2	10	78
301	1	1	48	24	14	8	94
311	4	5	249	116	77	28	470
312	1	1	39	23	--	3	65
313	5	5	243	138	55	31	467
321	6	5	326	177	59	28	590
322	5	4	302	115	90	32	539
324	2	6	124	112	112	49	397
333	1	1	20	13	8	4	45
342	2	1	91	31	17	--	139
344	0	1	1	11	12	4	28
351	1	2	57	22	24	13	116
352	1	2	53	36	15	15	119
353	3	0	134	63	6	--	203
361	2	1	123	44	25	13	205
Sub-Total *			4,907	2,435	1,608	714	9,664
Total**			5,134	2,508	1,664	718	10,004

* Includes only zones having both one- and two-car families.

** Adds information calculated for zones having only one- and zero-car families (101, 123, 141, 155, 205, 341) and zones added to the study (129, 331, 332) in the analysis of number 2 cards (see table next page).

(1) Zone number
(11) Per cent of one-car families per zone of total one-car families in all zones
(12) Per cent of two-car families per zone of total two-car families in all zones
(13) Number of non-student vehicular trips of one-car families with one in car per zone
(14) Number of non-student vehicular trips of one-car families with more than one in car per zone
(15) Number of non-student vehicular trips of two-car families with one in car per zone
(16) Number of non-student vehicular trips of two-car families with more than one in car per zone
(17) Total number of non-student vehicular trips per zone

Table A3 (continued)

Zone	Number One Car Families	Number Zero Car Families	Total Families	Total Number of Non-Student Vehicular Trips: One-Car Families: One in Car	One-Car Families: More Than One in Car	Two-Car Families: One in Car	Two-Car Families: More Than One in Car	Total
101	6	9	15	5	5	-	-	10
123	9	3	12	19	13	-	-	32
129	-	-	8	24	14	11	3	52
141	10	2	12	28	9	-	-	37
155	25	17	42	105	19	-	-	124
205	9	25	16	16	2	-	-	18
331	-	-	8	8	-	19	1	28
332	-	-	4	14	1	6	-	21
341	4	3	7	8	10	-	-	18
	63	59	124	227	73	36	4	340

Table A4

SURVEY ZONES REPORTED IN HOUSEHOLD INTERVIEW SAMPLE AND NOT USED IN ANALYSIS

Zone	Total Developed Acres	Student	Non-Student	Total Size
102	38	0	2	2
111	40	0	1	1
127	38	0	0	0
129	98	1	7	8
137	51	0	1	1
147	17	0	1	1
151	46	3	9	12
157	82	0	1	1
201	59	8	1	9
206	101	0	2	2
323	50	3	2	5
325	20	0	0	0
331	106	0	8	8
332	58	0	4	4
343	38	1	0	1
345	60	0	6	6
TOTAL 16	902	16	45	61

Table A5

SELECTED SOCIAL CHARACTERISTICS AND MEASURES OF TRAFFIC GENERATION BY NON-STUDENT HOUSEHOLDS BY SURVEY ZONE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
101	000	5	0.40	040.0	3.00	1.80	1.80	0.80
121	010	4	1.07	080.9	3.90	3.00	2.68	1.65
122	015	3	1.12	090.1	3.56	3.15	2.75	2.03
123	015	5	0.75	075.0	2.75	2.25	1.42	1.08
124	017	2	1.38	095.3	4.00	3.18	2.95	2.20
125	024	3	1.27	096.3	2.90	3.74	3.04	1.68
126	023	3	1.22	100.0	2.59	3.62	3.11	2.16
128	034	4	1.07	092.5	2.63	3.75	2.80	2.30
131	006	4	0.87	073.9	4.14	2.51	2.41	1.42
132	006	4	1.01	084.7	3.93	2.78	2.61	1.56
133	011	3	1.23	092.6	3.75	3.12	2.65	1.91
134	014	5	1.09	088.9	3.21	3.81	3.14	2.19
135	023	4	1.07	093.3	2.60	2.27	1.73	1.33
136	016	3	1.13	095.4	3.60	3.08	2.57	1.91
141	005	6	0.83	083.4	4.58	3.42	3.08	1.33
142	009	5	1.07	089.1	4.07	3.24	2.76	1.80
143	010	4	1.08	087.9	3.60	3.50	3.03	1.86
144	023	4	1.06	095.9	2.49	3.29	2.39	1.94
145	012	5	1.00	090.0	2.50	3.20	2.35	1.55
146	015	6	1.09	090.9	5.18	4.00	3.36	2.36
152	012	5	0.86	081.4	3.70	2.09	1.91	1.28
154	007	5	0.87	076.4	4.31	2.62	2.29	1.31
155	008	6	0.60	059.5	4.48	3.24	2.88	1.31
156	010	7	0.62	059.2	4.18	3.58	3.24	1.61
203	014	5	0.79	077.1	2.63	2.73	1.35	1.06
205	015	5	0.36	036.0	2.64	2.12	1.00	0.32
301	000	5	0.68	052.9	3.82	2.35	2.15	1.24
311	004	3	0.96	075.3	4.09	2.81	2.60	1.56
312	008	5	0.58	054.2	3.83	2.29	2.04	1.21
313	009	2	1.05	088.6	4.35	2.68	2.52	1.82
321	006	5	1.12	090.9	3.91	3.08	2.83	1.83
322	011	4	1.09	094.5	2.98	3.48	2.85	1.96
324	012	3	1.35	094.4	3.00	3.27	2.82	2.15
333	028	5	1.20	100.0	3.30	3.00	2.40	2.10
341	004	5	0.57	057.2	2.71	2.14	1.57	1.14
342	010	5	1.03	089.7	4.17	3.38	2.79	1.66
344	029	5	1.42	100.0	4.00	3.86	3.57	2.71
351	006	5	0.90	074.2	3.55	2.35	2.00	1.35
352	009	4	1.07	088.9	3.74	2.56	2.22	1.70
353	013	5	0.76	074.2	3.65	2.97	2.56	1.45
361	006	5	0.96	075.0	4.13	2.63	2.42	1.48

(1) Zone number
(2) Distance from CBD
(3) Socio-economic type
(4) Average number of cars per household
(5) Per cent of households with cars
(6) Average length of residence
(7) Average number of persons per household
(8) Average number of persons over five years of age
(9) Average number of persons making trips

Table A5 (continued)

(1)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
101	04.5	1.67	43.20	034.24	2.08	043	2.0
121	06.0	1.56	15.15	061.78	3.45	055	5.0
122	04.0	1.69	15.33	064.51	3.52	068	9.0
123	06.0	1.13	09.64	116.07	3.77	048	3.5
124	04.0	1.74	20.63	055.89	3.14	069	9.0
125	04.5	1.48	15.27	055.86	3.33	045	5.0
126	05.0	1.56	15.18	043.02	3.12	056	6.0
128	05.0	1.53	10.77	017.08	3.23	061	9.0
131	05.0	1.54	13.82	094.36	3.14	057	4.0
132	05.0	1.75	20.08	074.55	3.43	056	4.0
133	04.0	1.68	17.08	059.72	3.38	061	7.0
134	06.0	1.45	08.43	033.45	3.12	058	7.0
135	07.0	1.50	10.02	026.85	3.90	059	5.0
136	05.0	1.63	10.54	036.24	3.51	062	7.0
141	10.0	1.50	10.70	144.30	3.13	039	4.0
142	05.0	1.45	06.21	046.70	3.27	056	6.0
143	05.0	1.55	08.05	041.37	3.06	053	5.0
144	05.0	1.49	11.08	013.00	3.53	059	7.0
145	06.0	1.55	09.00	019.22	3.87	048	6.0
146	09.0	1.25	07.75	034.19	2.50	059	6.0
152	05.0	1.46	25.94	055.13	3.36	061	4.0
154	05.0	1.46	15.04	077.33	3.24	050	4.0
155	08.0	1.42	08.25	075.15	2.95	040	3.5
156	07.0	1.71	04.14	066.67	2.94	045	4.0
203	06.0	1.50	29.91	048.71	3.06	039	2.0
205	06.0	1.25	48.00	040.65	3.00	015	0.0
301	06.5	1.65	15.15	067.52	2.95	053	2.0
311	06.0	1.57	14.71	065.33	3.16	056	4.0
312	06.0	1.86	27.72	055.95	3.00	053	4.0
313	04.0	1.64	19.54	043.30	3.48	068	6.0
321	06.0	1.48	09.21	057.11	3.28	059	6.0
322	05.0	1.43	09.68	042.87	3.42	056	7.0
324	06.0	1.64	21.23	038.15	3.43	066	8.0
333	04.5	1.58	09.75	077.33	2.67	070	6.0
341	02.5	1.75	10.60	058.68	4.00	053	4.0
342	05.0	1.50	06.94	036.02	3.29	049	6.0
344	02.0	1.40	08.58	037.41	2.53	070	6.0
351	05.0	1.61	10.35	081.16	3.52	058	4.0
352	04.5	1.45	10.20	036.86	3.22	067	5.0
353	05.0	1.52	06.96	038.07	3.08	049	4.0
361	05.0	1.60	11.68	067.38	3.31	056	6.0

(1) Zone number
(10) Median average of vehicle in years
(11) Average make of vehicle (by price class)
(12) Average value of structures
(13) Coefficient of variability
(14) Average number of trips per person making trips
(15) Per cent of potential trip-makers making trips
(16) Median number of passenger trips per household

Table A6

SELECTED SOCIAL CHARACTERISTICS OF AND MEASURES OF TRAFFIC GENERATION BY STUDENT HOUSEHOLDS BY ZONES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
121	010	4	0.84	083.4	2.83	1.00	1.00	0.92	04.5	1.40	15.15	061.78	5.18	092	5.0
122	015	3	1.06	093.7	2.31	1.00	1.00	0.94	05.0	1.29	15.33	064.51	6.27	094	6.0
123	015	5	1.00	100.0	2.43	1.00	1.00	1.00	06.0	1.43	09.64	116.07	6.14	100	6.0
125	024	3	1.07	100.0	2.21	1.00	1.00	0.93	04.0	1.87	15.27	055.86	3.62	093	4.0
131	006	4	0.83	083.4	2.28	1.00	1.00	1.00	05.0	1.44	13.82	094.36	4.72	100	4.0
132	006	4	0.93	092.9	2.21	1.00	1.00	0.89	06.0	1.69	20.08	074.55	5.68	089	5.5
133	011	3	0.89	089.5	2.47	1.00	1.00	0.74	05.0	1.59	17.08	059.72	4.43	074	2.0
134	014	5	1.00	090.0	2.00	1.00	1.00	1.00	06.0	1.80	08.43	033.45	3.80	100	3.5
143	010	4	1.00	100.0	2.30	1.00	1.00	0.90	06.0	1.80	08.05	041.37	4.78	090	4.5
144	023	4	0.91	090.9	2.45	1.00	1.00	0.91	04.0	1.64	11.08	013.00	5.00	091	4.0
145	012	5	0.90	090.0	1.90	1.00	1.00	1.00	06.0	1.44	09.00	019.22	4.50	100	4.5
152	012	5	0.41	040.5	2.30	1.00	1.00	0.58	06.0	1.67	25.94	055.13	3.57	058	1.0
153	012	5	0.40	038.0	2.20	1.16	1.16	0.40	07.0	1.35	35.00	054.60	2.68	033	0.0
154	007	5	0.45	043.5	2.14	1.00	1.00	0.49	07.0	1.50	15.04	077.33	3.71	049	0.0
155	008	6	0.43	042.9	2.50	1.00	1.00	0.36	06.0	1.50	08.25	075.15	3.20	036	0.0
202	014	5	0.16	016.2	2.47	1.03	1.01	0.43	04.5	1.58	29.72	054.88	2.88	042	0.0
203	014	5	0.43	042.5	2.32	1.00	1.00	0.54	06.0	1.48	29.91	048.71	4.12	055	1.0
204	016	5	0.13	013.2	2.11	1.00	1.00	0.41	06.5	1.71	30.96	045.51	3.14	041	0.0
205	015	5	0.16	015.8	2.21	1.00	1.00	0.49	06.0	1.39	48.00	040.65	2.96	049	0.0
301	000	5	0.80	080.0	2.60	1.00	1.00	1.00	06.0	1.67	15.15	067.52	4.07	100	3.0
311	004	3	0.60	059.1	2.28	1.00	1.00	0.67	06.0	1.53	14.71	065.33	4.58	067	2.0
312	008	5	0.45	045.4	2.15	1.00	1.00	0.51	07.0	1.44	27.72	055.95	3.55	051	1.0
313	009	2	0.54	053.5	2.53	1.00	1.00	0.71	05.0	1.31	19.54	043.30	4.11	071	2.0
321	006	5	0.95	095.5	2.23	1.00	1.00	0.91	05.0	1.52	09.21	057.11	5.35	091	4.0
322	011	4	0.95	086.4	2.41	1.00	1.00	0.82	06.0	1.33	09.68	042.87	5.83	082	4.0
342	010	5	0.91	081.8	2.27	1.00	1.00	1.00	05.0	1.55	06.94	036.02	5.82	100	6.0
361	006	5	0.54	053.6	1.86	1.00	1.00	0.61	06.5	1.90	11.68	067.38	4.59	062	2.0

(1) Zone number
(2) Distance from CBD
(3) Socio-economic type
(4) Average number of cars per household
(5) Per cent of households with cars
(6) Average length of residence
(7) Average number of persons per household
(8) Average number of persons over five years of age
(9) Average number of persons making trips
(10) Median average of vehicle in years
(11) Average make of vehicle (by price class)
(12) Average value of structures
(13) Coefficient of variability
(14) Average number of trips per person making trips
(15) Per cent of potential trip-makers making trips
(16) Median number of passenger trips per household

Table A7

LAND USE OF TOTAL DEVELOPED ACRES PER SURVEY ZONE*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
101	----	----	83.3	16.7	----	51	----	51
121	68.4	21.1	----	----	10.5	169	----	169
122	81.8	----	3.0	3.0	12.2	293	----	293
123	32.7	----	32.7	32.7	----	52	102	156
124	70.6	----	----	----	29.4	320	----	320
125	90.7	----	3.0	----	6.3	300	19	319
126	78.9	----	5.1	----	15.6	237	387	624
128	94.3	----	5.7	----	----	140	124	264
131	35.0	60.0	----	----	5.0	173	----	173
132	41.2	47.0	5.9	----	5.9	126	----	126
133	84.6	11.5	----	----	3.9	212	----	212
134	73.4	5.1	5.1	15.8	----	177	28	205
135	47.3	----	----	47.3	5.5	146	69	215
136	80.0	5.0	----	10.0	5.0	189	----	189
141	----	----	33.3	66.7	----	365	----	365
142	77.0	8.0	----	8.0	8.0	100	15	115
143	70.8	6.2	6.2	11.8	6.2	161	170	331
144	81.4	----	7.3	4.0	7.3	177	20	197
145	28.6	----	14.3	42.9	14.3	105	195	300
146	50.0	----	----	50.0	----	73	776	849
152	7.1	71.6	7.1	7.1	7.1	124	----	124
154	5.6	72.2	11.0	5.6	5.6	156	----	156
155	5.0	80.0	5.0	5.0	5.0	111	----	111
156	54.6	13.5	----	27.0	4.3	185	50	235
203	----	46.7	----	----	53.3	120	24	144
205	----	23.1	7.7	----	69.2	114	----	114
301	----	37.5	37.5	12.5	12.5	69	----	69
311	52.0	48.0	----	----	----	191	----	191
312	----	100.0	----	----	----	49	----	49
313	60.0	20.0	----	----	20.0	239	----	239
321	90.9	----	----	9.1	----	205	----	205
322	85.8	10.9	----	----	3.8	211	45	256
324	90.9	----	----	----	9.1	292	1261	1553
333	28.4	----	----	22.2	49.4	81	1093	1174
341	----	----	57.4	----	42.6	61	18	79
342	66.7	25.3	----	----	8.1	99	25	124
344	----	----	44.8	----	55.2	29	454	483
351	55.1	9.0	9.0	18.0	9.0	89	----	89
352	15.7	----	----	----	84.3	191	75	266
353	94.1	----	----	2.9	2.9	170	43	213
361	25.0	75.0	----	----	----	101	----	101

(1) Zone
(2) Percentage of acres in single family residence
(3) Percentage of acres in multi-family residence
(4) Percentage of acres in commercial use
(5) Percentage of acres used for industry and railroad
(6) Percentage used for public and semi-public
(7) Total number of developed acres
(8) Total number of undeveloped acres
(9) Total number of acres (developed and undeveloped)

*--- indicates a very small number or no number

Table A8

DISTRIBUTION OF OCCUPATIONS OF DRIVERS OF VEHICLES

WITHOUT PASSENGERS BY SURVEY ZONE

(1)	(2)	(3)		(4)		(5)		(6)		(7)		(8)	
		N	Per Cent	N	Per Cent	N	Per Cent	N	Per Cent	N	Per Cent	N	Per Cent
101	2	0	(0)	0	(0)	0	(0)	2	(100)	0	(0)	9	(0)
121	88	7	(8)	19	(22)	10	(9)	2	(2)	21	(25)	23	(26)
122	135	13	(10)	24	(18)	14	(10)	6	(4)	33	(24)	38	(28)
123	7	0	(0)	2	(29)	0	(0)	0	(0)	1	(14)	3	(43)
124	138	22	(16)	11	(8)	6	(4)	2	(1)	67	(49)	28	(20)
125	118	17	(14)	14	(12)	8	(7)	3	(3)	43	(36)	25	(21)
126	52	10	(19)	7	(13)	4	(8)	0	(0)	14	(27)	15	(29)
128	53	5	(9)	6	(11)	5	(9)	4	(8)	18	(34)	6	(11)
129	12	1	(8)	0	(0)	1	(8)	4	(33)	0	(0)	5	(42)
131	64	3	(5)	14	(22)	13	(20)	5	(8)	11	(17)	10	(16)
132	78	9	(12)	12	(15)	10	(13)	1	(1)	17	(22)	14	(18)
133	128	13	(11)	20	(16)	13	(10)	2	(2)	38	(30)	32	(25)
134	72	2	(3)	9	(13)	14	(19)	10	(14)	9	(13)	12	(17)
135	9	0	(0)	0	(0)	1	(11)	1	(11)	2	(22)	4	(44)
136	114	9	(8)	15	(13)	17	(15)	3	(3)	33	(29)	28	(25)
141	8	2	(25)	0	(0)	2	(25)	1	(13)	2	(25)	0	(0)
142	39	1	(3)	4	(10)	17	(44)	3	(8)	5	(13)	2	(5)
143	61	1	(2)	8	(13)	11	(18)	5	(8)	10	(16)	10	(16)
144	56	6	(11)	11	(20)	7	(13)	4	(7)	12	(21)	9	(16)
145	33	4	(12)	1	(3)	3	(9)	3	(9)	9	(27)	6	(18)
146	12	0	(0)	0	(0)	2	(17)	1	(8)	6	(50)	0	(0)
152	37	8	(22)	6	(16)	1	(3)	4	(11)	6	(16)	8	(22)
154	42	4	(10)	5	(12)	8	(19)	3	(7)	7	(17)	10	(24)
155	46	0	(0)	1	(2)	14	(30)	8	(17)	6	(13)	1	(2)
156	66	1	(2)	2	(3)	5	(8)	18	(27)	13	(20)	1	(2)
203	13	2	(15)	3	(23)	0	(0)	0	(0)	7	(54)	1	(8)
205	6	0	(0)	1	(17)	0	(0)	0	(0)	2	(33)	1	(17)
301	21	1	(5)	3	(14)	4	(19)	0	(0)	7	(33)	5	(24)
311	113	19	(17)	26	(23)	7	(6)	3	(3)	24	(21)	27	(24)
312	13	1	(8)	1	(8)	2	(15)	1	(8)	3	(23)	5	(38)
313	97	3	(3)	4	(4)	6	(6)	1	(1)	37	(38)	46	(47)
321	131	14	(11)	23	(18)	26	(20)	12	(9)	26	(20)	11	(8)
322	122	4	(3)	24	(20)	14	(11)	6	(5)	27	(22)	40	(33)
324	73	3	(4)	4	(5)	2	(3)	1	(1)	32	(44)	31	(42)
331	11	1	(9)	2	(18)	5	(45)	1	(9)	1	(9)	1	(9)
332	9	0	(0)	1	(11)	0	(0)	2	(22)	5	(55)	0	(0)
333	11	0	(0)	1	(9)	5	(45)	1	(9)	1	(9)	1	(9)
341	2	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	1	(50)
342	35	0	(0)	8	(23)	5	(14)	5	(14)	5	(14)	9	(26)
344	5	0	(0)	0	(0)	0	(0)	2	(40)	1	(20)	0	(0)
351	34	0	(0)	5	(15)	9	(26)	4	(12)	9	(26)	6	(18)
352	29	5	(17)	3	(10)	4	(83)	1	(3)	8	(28)	5	(17)
353	47	3	(6)	3	(6)	5	(11)	10	(21)	12	(26)	6	(13)
361	55	6	(11)	10	(18)	4	(7)	9	(16)	10	(18)	12	(22)

(1) Zone number
(2) Total number of drivers of cars without passengers
(3) Number of drivers who are managers or officials and their (per cent of total drivers)
(4) Number of drivers who are clerical, sales, or kindred workers and their (per cent of total drivers)
(5) Number of drivers who are craftsmen, foremen, and skilled workers and their (per cent of total drivers)
(6) Number of drivers who are laborers and unskilled workers and their (per cent of total drivers)
(7) Number of drivers who are of miscellaneous occupations and their (per cent of total drivers)
(8) Number of drivers who are of the professions and semi-professions and their (per cent of total drivers)

B. DESCRIPTIONS OF THE VARIABLES CORRELATED WITH PASSENGER AND VEHICULAR TRIPS REPORTED IN THE CHAMPAIGN-URBANA O-D SURVEY

(Numbers correspond to items in Table 10 and Appendix D)

(1) Scale Value of Occupations

The construction of scale types involved taking the proportion of drivers in each of four occupations reported for all zones. These occupational categories were used: (a) professional and semi-professional, (b) proprietors, managers, and officials, (c) clerical, sales, and kindred workers, (d) craftsmen, foremen, skilled laborers, etc. Thus the range of occupations in the zones is from manual labor to professional occupations. Each zone was ranked above or below the median for each of the occupational categories.

(2) Median Sex-Race

This variable was based on the sex and race of driver arranged in the combinations of white male, white female, negro male, negro female. The zone medians, with the exception of one, were either white male or white female.

(3) and (4) Purpose From and To Home

This variable included purposes (other than home) of work,(1) business,(2) medical and dental,(3) school,(4) social recreation,(5) change travel mode,(6) eat meal,(7) shopping.(8) In both purpose from and to home, the zone medians were either work, business, or social recreation (for drivers). For more than one in car, the zone medians were 1,2,3,4,5,8 from home and 1,2,3,4,5,7,8 to home.

(5) Time of Trip -- Morning Median from Home

For this variable, the zone medians for drivers ranged from 7:00 to 10:00 in the morning (from a possible range of 1:00 a.m. to 1:00 p.m.). For more than one in car, the range was 7:00 to 11:00 in the morning.

(6) Time of Trip -- Afternoon Median from Home

For this variable, the zone medians for drivers ranged from 14 to 19, which means from 2:00 p.m. to 7:00 p.m. (from a possible range of 1:00 p.m. to 1:00 a.m.). For more than one in car, the range was from 13 to 19 in the afternoon.

(7) Time of Trip -- Morning Median to Home

For this variable the zone medians ranged from 8:00 a.m. to 12:00 noon (with the same possible range as (5)).

(8) Time of Trip -- Afternoon Median to Home

For this variable the zone medians ranged from 15 to 20, which means from 3:00 p.m. to 8:00 p.m. (with the same possible range as (6)). For more than one in car, the range was 13 to 20 in the afternoon.

(9) Median Number of Persons in Car

The zone medians were all 2, with the exception of zone 312, which was 3.

(10) Median Age of Auto-Drivers

The range of zone medians for this variable was from 25 years of age to 55 years of age for drivers. For more than one in car, the range was 25 to 60 years of age.

(11) Distance from CBD

For this variable, the range for the zones studied was from 00 (the central business district) to 36. Each figure is .10 of a mile from the nearest CBD.

(12) Socio-Economic Type

The possible, socio-economic types were highest (1), very high (2), above average (3), average (4), below average (5), low (6), and very low (7). These classifications were made in terms of such factors as type of residence, general appearance of residence and property, etc. The actual range in the zones studied was from 2 to 7, or from very low to very high.

(13) Average Number of Cars per Household

The range of zone averages for this variable was from .36 to 1.42.

(14) Average Length of Residence

The range of zone averages for this variable was from 2.50 (6 to 12 months) to 5.18 (11 to 15 years).

(15) Average Number of Persons per Household

For this variable, the zone averages had a range of 1.80 to 4.00, or roughly from two to four persons.

(16) Average Number of Persons Making Trips (Passenger Trips Included)

For this variable the range of zone averages was from .32 to 2.71.

(17) Median Year of Car Models

In this variable 1958 models were indicated by 1, 1957 by 2, 1956 by 3, etc. The range of zone medians was from 2 to 10, or from 1957 models to 1949 models.

(18) Average Make of Cars

Included in this variable were low priced cars (1), medium priced cars (2), and high priced cars (3). The range of zone averages was from 1.13 to 1.86, or roughly, from low priced to medium priced cars.

(19) Average Value of Structure

This variable is the average of the estimated monetary value of building structures (in thousands of dollars) in each zone. The range of averages for the zones studied was from 4.14 to 48.00.

(20) Percentage of Potential Trip-Makers Making Trips (Includes Passenger Trips)

The range of percentages for this variable was from 15 per cent to 70 per cent.

(21) Average Number of Trips per Person Making Trips (Passenger Trips Included)

In the zones studied, the range of averages for this variable was from 2.08 to 4.00, or from approximately 2 to 4 trips per person making trips.

(22) Median Number of Trips (Passenger Trips Included)

The range of zone medians for this variable was from 0 to 9.

(24) Number of Vehicular Trips per Developed Acre

In the zones studied, the range for this variable was from .10 to 3.08.

(25) Number of Developed Acres per Household

In the zones studied, the range for this variable was from 1.75 to 30.42.

(28) Homogeneity Factor in Terms of Car Type and Age

The range of this variable in the zones studied was from 5 to 1, that is, from zones with less than 29.6 per cent new cars and more than 53.8 per cent low priced cars to zones with more than 31.62 per cent new cars and more than 8.3 per cent high priced, less than 37.8 per cent medium priced, and less than 53.8 per cent low priced cars.

(29) Homogeneity Factor in Terms of Real Estate Values

From real estate values, a coefficient of variability was computed. There was a range from 1 to 5 in the zones studied. 1 = low variability (\$10-24,000); 2 = rather high variability (\$25-49,000); 3 = average variability (\$50-64,000); 4 = rather high variability (\$65-89,000); 5 = high variability (\$90-144,000).

C. SCALES FOR THE SURVEY ZONES

1. The Construction of Scales to Measure Levels of Industry, Occupation, and Heterogeneity of Survey Zones

Certain of the information secured in the course of the survey had to be converted to numerical values in order for it to be used in the various statistical analyses involving correlation. Examples of such information were the data on occupations and industrial employment of members of households. This data, secured through the household interview, provided crucial estimations of the socio-economic level of the survey zones in which the households were located. These findings, however, had to be translated into some numerical form. This translation was achieved by the method of "scaling" survey results. The same method was also used to define the degree of heterogeneity of each survey in respect to various measures of socio-economic level of the zones.

The methods used in these procedures were the standard techniques of scaling used by sociologists, either cumulative or Guttman-type scales.(16) The actual scales for occupation as developed are very similar to a number of scales which have been standard with social scientists for many years.(17)

The procedure for each scale was to convert the categories of households into proportions per each survey zone, and then to give a numberical value to each survey zone in terms of the pattern of proportions. The unit of scaling, therefore, was the survey zone. The phases of this operation and the nature of the data are shown by the sequence of tables at the end of this chapter.

2. Scales for Socio-Economic Level of Survey Zones

The socio-economic level or type of survey zone was a crucial measure in the study, since the main hypothesis of the investigation called for demonstrating the relation between this variable and rates of traffic generation by zone. Several measures of socio-economic level were used: (1) occupation, (2) average value of residence and age and make of vehicle, and (3) an estimate for each survey zone for its relative socio-economic level as represented by the residential desirability of the neighborhoods making up the zone. The latter measure appeared to give very consistant results. This estimate was made by staff members of the project who calculated the residential desirability of street blocks in each of the zones, totaled the estimates, and averaged the results to give the social-economic type of the zone.

A number of criteria entered into calculation, the most important of which was the size, age, and condition of the residence as calculated by the specifications noted below. Other criteria included the proportion of the area which was devoted to residential use; contiguity to amenities, i.e., parks; the condition of facilities, i.e., streets and alleys; and presence or absence of negative factors, i.e., industrial plants giving off smoke, fumes, noise, etc. The general assumption of this measure was that the greater the residential desirability of a survey zone, the higher its socio-economic type. Seven levels or types were established as the possible range by this measure of the survey zone. The specifications for each of these categories are as follows:

SPECIFICATIONS OF SURVEY ZONES AS TYPES OF SOCIO-ECONOMIC AREAS

Category		Description
1.	Highest	Contain many homes of Category I Dwelling types. Physical facilities such as streets, lighting, etc., in good repair. Streets clean, landscaping, and general attractiveness of surroundings. Either low residential density or expensive apartment houses. Only one such area normally in smaller cities and towns.
2.	Very high	Similar to Category I. Fewer pretentious homes, somewhat higher residential density, probably less variation in the residential styles.
3.	Above average	Well-kept homes and surroundings. Smaller lots than Categories I and II, few pretentious homes, but dwellings well-built with considerably similarity in style. Majority of residences from Dwelling Type Categories II and III.
4.	Average	Category IV dwellings dominate. Increased residential density. Many residences will appear to have been built at approximately the same date. Conversions to apartments are possible, but are generally limited by the house size. General impression of residential stability.
5.	Below average	Area is undesirable to a degree because of location. May be adjacent to industrial area, railroads, or larger business districts. Dwellings in Categories V through VII, but area shows little care of either dwellings or physical facilities. Large number of conversions to apartments or commercial uses. Evidence of residential mobility.
6.	Low	Run-down areas, inadequate care of residences and facilities. Streets may not be paved, lots fill with debris. Impression of overcrowding of dwellings in Categories VI through VIII.
7.	Very low	Dwellings in Categories VII-VIII. Real slum condition. Located near factories, dump-heaps, gas tanks, etc. Generally characterized by other forms of land use in addition to residence.

SPECIFICATIONS OF RESIDENCES AS CRITERIA OF SOCIO-ECONOMIC LEVEL OCCUPATIONS

(Specifications of residences and dwelling types are modifications of procedures described by W. L. Warner, Social Class in America.)[18]

Specifications of Dwelling Types

	Category	Description
1.	Excellent	Large houses, eight rooms or more, single-family dwellings in good repair, surrounded by large lawn or yard in state of good care and landscaping.
2.	Very good	Category I houses in state of medium repair with surroundings in state of medium to good care. Medium-sized houses, seven or eight rooms but smaller in total size than Category I, but in same state of repair and care as Category I. Large apartments, six rooms or more in regular apartment houses in good repair.
3.	Good houses	Category I houses and Category II houses in a state of poor to fair repair and poor to fair care of grounds. House lot size smaller than Category I and II. Category II apartments in regular apartment houses in fair repair.
4.	Average houses	One and one-half story to two-story wood or brick in good repair. Lawns well-kept. Four to six rooms average size. Four- and five-room apartments in regular apartment houses in good state of repair.
5.	Fair houses	Category IV houses in medium repair and care. Three-room houses in good repair. One and one-half- to three-room apartments in regular apartment houses in good repair. Four- to five-room apartments in regular apartment houses in medium repair.
6.	Below average	Any Category III, IV, V houses in poor repair, run-down, but could be repaired. Three- to five-room apartments in converted dwellings, or two-room apartments in converted dwellings which are in a state of excellent repair.
7.	Poor houses	Two-room houses in good repair, larger houses badly deteriorated, one- and two-room apartments in converted dwellings in poor repair.
8.	Very poor houses	One-room houses, buildings not originally intended as dwellings, shacks, and any buildings unsafe and unhealthy or not repairable to minimum standards of occupancy. Such dwellings may have no yards, premises littered with junk and refuse, in many cases are overcrowded.

D. ROTATED FACTOR LOADINGS FROM FACTOR ANALYSIS OF HOUSEHOLD TRAITS ASSOCIATED WITH TRAFFIC GENERATION

The study focused on the relation of attributes of households, averaged by survey zones, to measures of traffic generation also expressed as indices of survey zones. Since the study was an exploration of this relation, a number of measures were introduced simply to ascertain their degree of association with the generation of traffic. Factor analysis is an ideal technique for an efficient exploration of possible relationships between items. In this case two factor analyses revealed several patterns of association between household traits and measures of traffic production. On the basis of these analyses it was possible to develop correlations of multiple regression which suggested household traits which would serve as the best predictors of traffic generation.

The findings of the factor analyses have been summarized in the body of the report in Tables 12 and 13. The loadings for all items on the whole set of factors are shown in Tables D1 and D2. The description of each of the twenty-eight household traits which were introduced into the study is also given in terms of the derivation of the data, when they were not based on the household survey, and of the range in measures of the items.

Table C1

FREQUENCY DISTRIBUTIONS BY PERCENTAGES OF OCCUPATIONS WITHIN ZONES

(The per cent is determined from the ratio of (1) the number of drivers who belong to the designated occupational category to (2) the total number of persons in the zone who drive automobiles without other passengers.)

Per Cent	(A)	(B)	(C)	(D)	(E)	(F)
0	12	7	7	6	3	5
1- 5	9	5	3	12	-	3
6-10	9	6	12	12	2	4
11-15	8	11	8	6	5	2
16-20	4	9	7	2	8	10
21-25	2	5	1	2	9	8
26-30	-	1	2	1	7	4
31-35	-	-	-	1	3	1
36-40	-	-	-	1	2	1
41-45	-	-	3	-	-	4
46-50	-	-	-	-	2	2
51 and above	-	-	1	1	3	-
TOTAL	44	44	44	44	44	44

(A) Managers and officials

(B) Clerical, sales, and kindred workers

(C) Craftsmen, foremen, and skilled workers

(D) Laborers and unskilled workers

(E) Miscellaneous occupations

(F) Professions and semi-professions

Table C2

OCCUPATIONAL CLASSIFICATION REPORTED FOR DRIVERS, TRIP FROM HOUSE

Source: Household Interview

Occupational Rating	Number of Persons
0 - Professional and Semi-professional	498
1 - Proprietors, Managers, and Officials	202
2 - Clerical, Sales, and Kindred Workers	313
3 - Craftsmen, Foremen, Skilled Laborers	284
4 - Farmers and Farm Managers	5
5 - Protective Service Workers	57
6 - Operatives and Semi-Skilled Workers	93
7 - Service Workers (except domestic and protective)	91
8 - Laborers and Unskilled Workers	154
9 - Miscellaneous	600

Total number of persons = 2,297

Table C3

DISTRIBUTION OF OCCUPATIONS OF DRIVERS BY SURVEY ZONE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
101	2	0	0	0	0	0	0	2	100	0	0	0	0
121	88	7	8	19	22	10	9	2	2	21	25	23	26
122	135	13	10	24	18	14	10	6	4	33	24	38	28
123	7	0	0	2	29	0	0	0	0	1	14	3	43
124	138	22	16	11	8	6	4	2	1	67	49	28	20
125	118	17	14	14	12	8	7	3	3	43	36	25	21
126	52	10	19	7	13	4	8	0	0	14	27	15	29
128	53	5	9	6	11	5	9	4	8	18	34	6	11
129	12	1	8	0	0	1	8	4	33	0	0	5	42
131	64	3	5	14	22	13	20	5	8	11	17	10	16
132	78	9	12	12	15	10	13	1	1	17	22	14	18
133	128	13	11	20	16	13	10	2	2	38	30	32	25
134	72	2	3	9	13	14	19	10	14	9	13	12	17
135	9	0	0	0	0	1	11	1	11	2	22	4	44
136	114	9	8	15	13	17	15	3	3	33	29	28	25
141	8	2	25	0	0	2	25	1	13	2	25	0	0
142	39	1	3	4	10	17	44	3	8	5	13	2	5
143	61	1	2	8	13	11	18	5	8	10	16	10	16
144	56	6	11	11	20	7	13	4	7	12	21	9	16
145	33	4	12	1	3	3	9	3	9	9	27	6	18
146	12	0	0	0	0	2	17	1	8	6	50	0	0
152	37	8	22	6	16	1	3	4	11	6	16	8	22
154	42	4	10	5	12	8	19	3	7	7	17	10	24
155	46	0	0	1	2	14	30	8	17	6	13	1	2
156	66	1	2	2	3	5	8	18	27	13	20	1	2
203	13	2	15	3	23	0	0	0	0	7	54	1	8
205	6	0	0	1	17	0	0	0	0	2	33	1	17
301	21	1	5	3	14	4	19	0	0	7	33	5	24
311	113	19	17	26	23	7	6	3	3	24	21	27	24
312	13	1	8	1	8	2	15	1	8	3	23	5	38
313	97	3	3	4	4	6	6	1	1	37	38	46	47
321	131	14	11	23	18	26	20	12	9	26	20	11	8
322	122	4	3	24	20	14	11	6	5	27	22	40	33
324	73	3	4	4	5	2	3	1	1	32	44	31	42
331	11	1	9	2	18	5	45	1	9	1	9	1	9
332	9	0	0	1	11	0	0	2	22	5	55	0	0
333	11	0	0	1	9	5	45	1	9	1	9	1	9
341	2	0	0	0	0	0	0	0	0	0	0	1	50
342	35	0	0	8	23	5	14	5	14	5	14	9	26
344	5	0	0	0	0	0	0	2	40	1	20	0	0
351	34	0	0	5	15	9	26	4	12	9	26	6	18
352	29	5	17	3	10	4	83	1	3	8	28	5	17
353	47	3	6	3	6	5	11	10	21	12	26	6	13
361	55	6	11	10	18	4	7	9	16	10	18	12	22

(1) Zone number
(2) Total number of drivers of cars without passengers
(3) Number of drivers who are managers or officials
(4) Per cent of total drivers who are managers or officials
(5) Number of drivers who are clerical, sales, or kindred workers
(6) Per cent of total drivers who are clerical, sales, or kindred workers
(7) Number of drivers who are craftsmen, foremen, and skilled workers
(8) Per cent of total drivers who are craftsmen, foremen, and skilled workers
(9) Number of drivers who are laborers and unskilled workers
(10) Per cent of total drivers who are laborers and unskilled workers
(11) Number of drivers who are of miscellaneous occupations
(12) Per cent of total drivers who are of miscellaneous occupations
(13) Number of drivers who are of the professions and semi-professions
(14) Per cent of total drivers who are of the professions and semi-professions

Table C4

CONSTRUCTION OF SCALES ON INDUSTRY, OCCUPATION, AND HETEROGENEITY -- SCALES AND WEIGHTS

Identification of Scale	Industry Weight		Occupation Weight	
Composition	Order (1 2 3) 1. Manufacturing 2. Construction or transportation 3. Professions or trade		Order (1 2 3) 1. Laborers and unskilled 2. Craftsmen, foremen, and skilled or clerical, sales, and kindred workers 3. Professions and Semi-professions or managers and officials	
Weights for Scale Types	Weight Scale Type*	Number of Zones	Weight Scale Type*	Number of Zones
	1: 001	10	1: 001	5
	2: 011	8	2: 011	16
	3: 010	7	3: 010	8
	4: 111	14	4: 111	5
	5: 110	5	5: 110	4
	6: 100	--	6: 100	6
Comment	A category receives a "1" if the per cent in the zone who work in that industry is equal to or greater than the median per cent for all zones (a "0" is received if this per cent is less than the median)0 per cents for zones are included in the determination of the median.		A category receives a "1" if the per cent in the zone who work in that occupation is equal to or greater than the median per cent for all zones (a "0" is received if this per cent is less than the median)0 per cents for the zones are included in the determination of the median.	

Identification of Scale	Heterogeneity Rating		
Composition	This rating indicates the lack of agreement between:		
	Reversed Occupation Weight	Average Make of Car	Weight of Zone Average of Individual House Values
	6	1.13-1.42	1
	5	1.43-1.49	2
	4	1.50-1.55	3
	3	1.56-1.63	4
	2	1.64-1.69	5
	1	1.70-1.86	6
Weights for Scale Types	Weight	Scale of Heterogeneity	Number of Zones
	0:	Complete Agreement	3
	1:	One error	16
	2:	Two errors	5
	3:	Three errors	8
	4:	Four errors or more	2
Comment	See Occupation Scale and Weight of Zone Average of Individual House Values on this table to compare with Average Make of Car		

*When there are two industries in any single category that category receives "1" if either or both industries placed in that category qualify for a score of "1" which indicates a proportionately prevalent number of workers in that industrial category.

Table C5

SCALE VALUES AND OTHER SOCIAL CHARACTERISTICS OF SURVEY ZONES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
101	3	6	---	-	2	0.30103	0.40	5
121	4	2	4.09356	4	5	0.69897	1.07	4
122	4	2	4.24016	6	9	0.95424	1.12	3
123	2	2	---	-	3.5	0.54427	0.75	5
124	1	1	4.29402	6	9	0.95424	1.38	2
125	2	1	4.15666	5	5	0.69897	1.27	3
126	4	2	4.17177	5	6	0.77815	1.22	3
128	1	6	3.99624	3	9	0.95424	1.07	4
129	4	3	4.07645	4	-	---	----	-
131	2	3	4.00980	4	4	0.60206	0.87	4
132	3	2	4.18517	5	4	0.60206	1.01	4
133	4	2	4.16933	5	7	0.84510	1.23	3
134	5	5	3.91515	3	7	0.84510	1.09	5
135	4	3	4.03410	4	5	0.69897	1.07	4
136	4	2	4.00505	4	7	0.84510	1.13	3
141	4	4	3.73758	1	4	0.60206	0.83	6
142	5	3	3.77582	1	6	0.77815	1.07	5
143	5	3	3.88396	2	5	0.69897	1.08	4
144	4	2	4.04689	4	7	0.84510	1.06	4
145	2	3	3.78587	1	6	0.77815	1.00	5
146	5	3	3.86443	2	6	0.77815	1.09	6
152	1	4	4.14243	5	4	0.60206	0.86	5
154	4	2	4.04102	4	4	0.60206	0.87	5
155	2	5	3.89091	2	3.5	0.54407	0.60	6
156	3	6	3.61928	1	4	0.60206	0.62	7
203	3	2	---	-	2	0.30103	0.79	5
205	1	3	---	-	0	---	0.36	5
301	1	2	4.07772	4	2	0.30103	0.68	5
311	2	2	4.06776	4	4	0.60206	0.96	3
312	4	2	4.10000	5	4	0.60206	0.58	5
313	1	1	4.10093	5	6	0.77815	1.05	2
321	4	4	3.93958	3	6	0.77815	1.12	5
322	2	2	3.95827	3	7	0.84510	1.09	4
324	2	1	4.39774	6	8	0.90309	1.35	3
331	3	5	3.99132	3	-	---	----	-
332	3	6	3.98630	3	-	---	----	-
333	4	5	---	-	6	0.77815	1.20	5
341	1	1	3.98129	3	4	0.60206	0.57	5
342	1	4	3.89570	2	6	0.77815	1.03	5
344	1	6	---	-	6	0.77815	1.42	5
351	4	2	3.95667	3	4	0.60206	0.90	5
352	1	2	3.99509	3	5	0.69897	1.07	4
353	3	6	3.78644	1	4	0.60206	0.76	5
361	5	4	4.00629	4	6	0.77815	0.96	5

(1) Zone number
(2) Industry weight (1: professions, 6: manufacturing)
(3) Occupation weight (1: professions, 6: laborers and unskilled)
(4) Log of zone average of individual house values
(5) Weight of zone average of individual house values (1: low, 6: high)
(6) Median number of passenger trips per household
(7) Log of median number of passenger trips per household
(8) Average number of cars per household
(9) Socio-economic type

Table D1

ROTATED ORTHOGONAL FACTOR LOADINGS ON TWENTY-EIGHT VARIABLES ASSOCIATED WITH VEHICULAR TRIPS CONTAINING ONLY DRIVER IN THE CAR -- CENTROID SOLUTION WITH FIXED COMMUNALITIES

1	-.612	-.307	+.253	+.335	-.145	-.068	+.264	+.284	+.144	+.058
2	-.263	-.443	-.281	+.245	+.246	+.322	+.200	+.167	+.241	-.148
3	+.097	-.658	-.274	+.261	-.330	-.197	-.066	+.277	-.043	-.176
4	+.108	-.722	-.219	+.275	-.288	-.219	-.192	+.225	-.111	-.154
5	+.143	-.355	-.164	+.391	-.405	-.168	-.432	-.265	+.177	-.221
6	-.262	+.158	-.135	-.206	+.326	-.539	-.250	-.228	+.187	-.118
7	+.334	-.295	+.203	-.335	-.136	+.212	-.103	+.309	-.347	+.240
8	+.156	-.408	-.509	-.285	+.185	-.403	-.112	+.181	+.143	+.241
9	-.242	+.633	+.185	-.241	-.339	+.103	-.122	+.225	+.172	-.122
10	+.440	-.171	+.578	+.263	+.332	-.054	+.070	-.073	+.160	-.237
11	-.710	-.059	-.128	+.370	+.138	+.130	+.160	+.109	+.142	+.231
12	+.749	+.332	+.291	+.313	+.023	-.133	-.134	-.106	-.163	-.038
13	-.317	+.685	-.262	+.198	-.237	-.071	-.279	+.109	+.169	+.108
14	+.420	+.358	+.237	+.534	+.389	+.202	-.180	+.038	+.064	-.043
15	+.681	+.455	+.317	+.404	+.065	-.046	-.068	+.026	+.153	+.100
16	-.484	+.143	-.208	+.323	+.348	+.242	-.294	+.296	-.231	-.161
17	+.237	+.333	-.170	-.396	-.411	+.239	+.390	+.157	+.109	-.154
18	-.293	-.368	+.230	-.494	-.288	+.212	-.282	-.214	+.078	-.286
19	+.649	+.414	+.130	+.104	-.309	-.290	+.128	+.074	+.121	+.179
20	+.416	-.213	-.438	-.183	+.297	-.247	+.345	+.084	-.324	-.083
21	+.784	+.378	+.179	+.167	+.214	-.084	-.023	+.075	+.096	+.039
22	+.655	+.399	-.370	-.136	+.302	+.149	+.188	+.193	+.074	-.097
23	+.588	+.351	-.433	-.195	+.049	+.182	-.319	-.194	+.069	+.146
24	-.362	+.174	+.263	+.213	+.205	-.319	+.155	+.362	-.411	-.290
25	+.609	+.140	-.211	+.252	-.192	+.476	+.101	-.157	-.170	-.065
26	+.684	+.449	-.294	-.171	+.227	+.117	+.112	+.155	+.060	-.078
27	-.410	-.155	-.398	+.420	+.405	+.216	-.146	-.085	-.192	+.135
28	-.316	+.211	-.465	-.119	-.201	-.288	-.142	+.330	-.153	-.091

1 Scale value of occupations
2 Median sex-race
3 Purpose from home
4 Purpose to home
5 Time of trip -- morning median from home
6 Time of trip -- afternoon median from home
7 Time of trip -- morning median to home
8 Time of trip -- afternoon median to home
9 Median age of auto-drivers
10 Distance from CBD
11 Socio-economic type
12 Average number of cars per household
13 Average length of residence
14 Average number of persons per household
15 Average number of persons making trips (passenger trips included)
16 Median year of car models
17 Average make of cars
18 Average value of structure
19 Percentage of potential trip-makers making trips (passenger trips included)
20 Average number of trips per person making trips (passenger trips included)
21 Median number of trips (passenger trips included)
22 Average number of trips per car (vehicular traffic)
23 Number of vehicular trips per developed acre
24 Number of developed acres per household
25 Average number of trips per car, two-car households
26 Average number of trips per car, one-car households
27 Homogeneity factor in terms of car type and age
28 Homogeneity factor in terms of real estate values

Table D2

ROTATED ORTHOGONAL FACTOR LOADINGS ON TWENTY-NINE VARIABLES ASSOCIATED WITH VEHICULAR TRIPS CONTAINING DRIVER AND ONE OR MORE PASSENGERS IN CAR -- CENTROID SOLUTION WITH FIXED COMMUNALITIES

1	-.583	-.094	+.279	+.383	-.394	-.057	+.132	+.195	+.166	-.174
2	-.383	+.302	+.482	-.298	-.081	+.184	-.153	-.227	-.225	-.076
3	-.087	-.269	+.210	-.245	+.491	-.372	-.247	+.474	-.113	-.100
4	+.075	-.589	-.103	-.164	+.224	-.429	-.328	+.226	+.222	-.200
5	-.342	-.509	-.159	+.122	+.354	+.126	+.100	-.342	+.139	+.299
6	+.431	+.280	+.203	-.204	+.322	-.364	+.342	-.161	+.082	+.232
7	-.351	+.275	+.187	-.253	+.163	+.339	+.220	+.094	-.386	+.219
8	+.531	+.297	-.107	+.329	+.161	-.268	+.262	-.122	-.229	-.243
9	-.195	+.301	-.567	+.314	+.301	+.110	+.097	+.099	-.205	-.280
10	-.230	+.137	-.355	-.148	-.246	+.335	-.324	+.357	+.339	+.138
11	+.442	-.343	+.478	+.254	+.150	+.235	-.181	+.230	+.089	-.208
12	-.628	+.258	+.266	+.136	-.299	-.192	-.070	-.205	+.236	-.264
13	+.789	+.100	+.227	+.272	+.218	-.095	-.147	+.197	-.102	+.129
14	-.158	+.690	-.275	+.229	+.196	-.261	-.133	-.175	+.141	+.127
15	+.490	+.347	+.536	+.229	+.171	+.204	-.332	-.129	+.142	-.104
16	+.764	+.281	+.200	+.438	+.117	+.083	-.216	+.059	+.046	+.038
17	-.479	+.443	+.416	-.235	+.209	+.081	+.060	-.115	+.254	-.049
18	+.242	+.288	-.540	-.181	-.314	+.349	+.103	+.255	-.204	-.148
19	-.452	-.480	-.365	-.167	+.167	+.355	-.215	+.047	-.255	+.065
20	+.723	+.206	-.238	+.385	-.047	-.127	+.075	+.253	-.066	+.147
21	+.398	-.168	+.144	-.538	-.207	-.208	+.460	+.192	+.185	+.248
22	+.852	+.175	+.140	+.180	+.078	+.149	-.061	+.183	+.141	+.097
23	+.735	+.362	-.076	-.375	-.049	+.196	+.147	+.031	+.257	-.077
24	+.621	+.275	-.371	-.365	+.134	-.123	-.235	-.185	+.028	+.152
25	-.350	+.240	+.460	+.171	+.225	+.118	+.379	+.422	+.054	+.085
26	+.610	+.224	+.151	-.313	-.224	-.120	-.266	-.066	-.405	-.063
27	+.770	+.330	-.159	-.302	+.051	+.169	+.097	+.058	+.248	-.070
28	-.405	+.224	+.430	-.333	-.154	-.335	-.199	-.122	+.269	-.082
29	-.301	+.371	-.319	-.192	+.299	-.406	+.260	+.163	+.138	-.260

1 Scale value of occupations
2 Median sex-race
3 Purpose from home
4 Purpose to home
5 Time of trip -- morning median from home
6 Time of trip -- afternoon median from home
7 Time of trip -- morning median to home
8 Time of trip -- afternoon median to home
9 Median age of auto-drivers
10 Median number of persons in car
11 Distance from CBD
12 Socio-economic type
13 Average number of cars per household
14 Average length of residence
15 Average number of persons per household
16 Average number of persons making trips (passenger trips included)
17 Median year of car models
18 Average make of cars
19 Average value of structure
20 Percentage of potential trip-makers making trips (passenger trips included)
21 Average number of trips per person making trips (passenger trips included)
22 Median number of trips (passenger trips included)
23 Average number of trips per car (vehicular traffic)
24 Number of vehicular trips per developed acre
25 Number of developed acres per household
26 Average number of trips per car, two-car households
27 Average number of trips per car, one-car households
28 Homogeneity factor in terms of car type and age
29 Homogeneity factor in terms of real estate values

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